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THE AURORA OF MARCH 22-25, 1920, AND ASSOCIATED DISPLAYS.¹

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[Weather Bureau, Washington, D. C., Aug. 25, 1920.]

SYNOPSIS.

A disturbed area marked by a group of sunspots stretching more than a quarter of the way across the face of the sun, bombarded the earth with such an abundance of electrified atoms that it caused an intense magnetic storm and an extraordinarily active and brilliant aurora, lasting for 20 hours and followed by 3 days of lesser magnetic and auroral activity. The beginning of the aurora was observed at Tatoosh Island, Washington, and in Australia practically simultaneously; then it became visible at dusk successively around the world until the last of its brilliance was seen toward dawn in the northwestern United States.

The numerous reports show not only that the periods of greatest brilliance and maximum magnetic activity were simultaneous throughout the world, but also that the general aspect of the display as a whole was similar. The local differences depended largely on the positions of the observers relative to the great series of auroral curtains. Great activity, some brilliant colors, especially crimson, and great vibrations of the whole display were characteristic features.

Some 100 reports received from parts of eastern North America have made it possible to map the actual locations of the brilliant auroral curtains at particular times, and thus to picture what might be called the geography of the aurora.

Auroras and magnetic disturbances occurred in mid-February, mid-April and mid-May, during the preceding and following presentations of the same active region on the sun, as it rotated.

This aurora ranks among the greatest five world-wide displays of the past 5 (or, in fact, 11) years, embracing the recent unusual sunspot maximum. In many places this aurora was the most brilliant one seen in this century.

INTRODUCTION.

Of all the phenomena of the heavens, what can vie with the magnificence of the aurora? Those who saw the display of the night of March 22-23, 1920, in all its grandeur, whether in France, England, or the northern half of the United States, have found it impossible to give an adequate word picture of the beauty of the sky filled with a ribbed dome and waving colored curtains of flaming lights.

The various descriptions received from places throughout the length and breadth of the United States, from Canada, from steamers on the Atlantic Ocean, and from Great Britain, France, Switzerland, and Germany, show that this aurora consisted of a great number of luminous curtains, extending, roughly, east and west, joined by an uneven sheet of light and grouped together into two great belts, probably encircling the north and south magnetic poles, with its outer edge at a distance of 3,500 to 4,000 kilometers, and most brilliant in apparently the outer 500 or 1,000 kilometers.²

THE LONG SUNSPOT GROUP.

What made this display, and when did it start?

"On March 19 a new large group [of sunspots] was seen near the east limb [of the sun], showing remarkably complicated structure. The

whole group extended over about one-fifth of the solar diameter, and observations on March 22, 23, 25 indicated rapid variations. There were three main spot centers, occupying the preceding and following ends and the center of the group, respectively, while the whole of the intermediate area was occupied by a great number of small umbrae. Spectro-heliograms on the above days, taken in calcium light, show the whole group as a connected mass, but the accompanying flocculae were not specially prominent. It is interesting to note that this spot group was at very low solar latitude, almost equatorial, and that it passed central meridian about March 22."—*The Observatory*, April, 1920, p. 166.

"It was the biggest group of sun spots observed since August, 1917, and its disk area, in units one five-thousandths of the visible disk, was 34 on March 22."—*A. L. Cortie*.³

"Not since the founding of the [Juvisy] Observatory [France] in 1883 had such a long group of sunspots been seen as were visible even to the naked eye after March 15. It was at least 500,000 km. long, measuring 22 mm. on the photograph in which the sun's diameter is 80, and the diameter of the earth on the same scale is less than 1 mm."—*G. Renaudot*.⁴

THE MAGNETIC STORM.

The arrival of the first cloud of electrified particles from this active area on the sun was registered at magnetic observatories throughout the world, in high as well as in low latitudes, simultaneously March 22 at 9h. 9m. G. M. T. (Among 10 observatories 9h. 6m. is the earliest and 9h. 12m. the latest time of beginning noted.)

"The [magnetic] storm began abruptly * * *, four hours of moderate activity being followed by about 6 hours of much greater activity. After a lull in the storm for three or four hours, the most severe portion began an hour or two before midnight [G. M. T.] and continued up to about 7h. on the 23d. The principal portion of the storm ended about [two or] three hours later, but there was considerable activity, particularly at Sitka, up to the end of the 25th."—*D. L. Hazard*.⁵

We should expect from this that there would be relatively little auroral activity from 9h. to 13h., a considerable display from 13h. to 19h., relative quiescence from 19h. to 22h. or 23h., great auroral brilliance from 22h. or 23h. till 7h. on the 23d, and considerable aurora from 7h. to 9h. or 10h., followed by a moderate aurora till the end of the 25th.

THE AURORA APPEARS IN BOTH HEMISPHERES.

The aurora was first observed almost simultaneously at 12h. 55m. G. M. T. at Tatoosh Island, Wash., and at 13h. at Cape Leeuwin (lat. 34° S.), West Australia:

1. *Tatoosh Island, Wash.*—A vivid aurora was observed from 4:55 a. m. to 5:17 a. m., extending from WNW to ENE., and within a few degrees of the zenith. It consisted of large streamers at uniform distances from one another with smaller and less vivid streamers between them. About one-third of the way down from their upper extremities their color was a reddish hue; this color also showed on the sky between the streamers and extended down several degrees, constantly changing like the reflection from the sky of a distant fire.—*C. D. Asher* (U. S. Weather Bureau).

¹ *Nature* (London), Apr. 1, 1920, p. 137.

² *Astronomie*, Apr., 1920, pp. 154-155, with photo of sun Mar. 22. For a photo of the sun Mar. 23, see *Popular Astronomy*, May, 1920, plate 14, and for a discussion of its appearance on the 23d and speculation as to its relation to the aurora, see *Science*, May 14, 1920, p. 486.

³ *Terr. Magnet. and Atmos. Elec.*, June, 1920, vol. 25, no. 2, pp. 57-59. See also pp. 60 and 61, and *Nature* (London), Apr. 1 and 8, 1920, pp. 136-138 and 170, for detailed accounts of foreign observations.

⁴ Presented in part before the American Meteorological Society, Washington, D. C., Apr. 22, 1920.

⁵ See Elias Loomis, "A treatise on meteorology," etc., New York, 1885, p. 187, for a map of auroral activity in the northern hemisphere. The whole section, pp. 173-201, includes an interesting exposition of facts concerning the aurora polaris.

"According to the 'West Australian,' Perth, March 24, 1920, fine auroral displays were observed by the lighthouse keeper at Cape Leeuwin from 9 p. m. to 3 a. m. [13^h-19^h G. M. T.] on the night of March 22 to March 23, at other stations along the south coast as far as Adelaide, at Kalgoorlie, and faintly at Perth about 3 a. m., March 23."

"An aurora was observed between 2^h and 2^h 30^m [120th E. mer. time] on March 23 [at Watheroo Magnetic Observatory, West Australia]; it appeared as a pale, but distinct, pink glow above the clouds [the dark segment?] on the southern horizon, losing color and fading away gradually."⁶

An hour before the aurora was last seen in Australia it became visible in Europe.⁷ When it was so bright in Australia as to be visible at Perth (19^h. G. M. T.) the whole northern sky as seen from near Hamburg, Germany, was covered with such a bright sheet of auroral light that second magnitude stars could hardly be seen. Two bands across the sky looked as bright "as if lighted by the full moon when rising." The disappearance of the display after this in Australia was marked in Germany by a rapid retreat of the lights toward the north and a marked decrease in brilliance.

A well-defined arch with a dark segment in the north first became manifest at 19^h. 17m. (G. M. T.), and immediately thereafter the display began to increase in brightness and to show beautiful patches of crimson light. At 19^h. 30m. the light was bright enough to distinguish pencil writing but not to read. The dark segment reached to a height of about 14°, indicating that the arch must have been overhead across Denmark and south Sweden. At 19^h. 53m. the display rapidly collapsed, and the dark segment approached the horizon; at 20^h. 35m. the light extended all the way to the northern horizon. Thick fog then blotted the display from sight.⁸

The aurora, however, was still visible in East Prussia till 1^h. (G. M. T.), March 23.

In a short note, Dr. J. Maurer, director of the Swiss meteorological service, says that this aurora was seen even from southern Switzerland, and that this was the first impressive display since that of September 9, 1898. In fact, there has been an unusual scarcity of auroral displays in Switzerland since 1875. Prior to that there was a period of relatively frequent auroras from 1830 to about 1870, when the last great aurora of this long series occurred.⁹

THE SECOND BRILLIANT PHASE BEGINS.

With the beginning of the magnetically active period, long vertical rays were seen to shoot up from the previously quiescent auroral glow in the north, as seen from Juvisy, France. But the activity died down at 23^h. 40m., and at 23^h. 45m. there was only a feeble luminous arc near the horizon. Rejuvenation took place during the next ten minutes, followed again by a weakening. This section of the display was finished with a brilliant intensification of the light in an arch covering all the NW. and N. sky at 23^h. 58m. At 1^h. the 23d (cf. 8 p. m. in the eastern United States, see below):

"The spectacle became prodigiously beautiful; the aurora developed in all its splendor; the northern sky was covered with a brilliant phosphorescence, streaked with gigantic rays in the north up to the Great Bear, nearly to the zenith, in the west to the brilliant Jupiter, and also to the east, to the northeast, in all directions of the sky on an angular extent of more than 180 degrees.

And all this fiery luminosity was in vibration, animated by strange pulsations. [At 1^h. 30m. the lights had died down, as in the U. S.]"—G. Renaudot.¹⁰

The vibrations of light, so noticeable in North America during this display, began simultaneously in Europe and the United States, being noted at 1^h. 22m. G. M. T. at Washington, D. C. In other respects, likewise, the aurora at Washington was much the same.

The display was also seen in Great Britain. At Eskdalemuir (lat. 55½°), Scotland, there was "an auroral display, including the 'curtain' form at a considerable altitude, and extending at 0^h. 50m. on March 23, to within 30° of the southern horizon."—A. C. Mitchell.¹¹ [Compare Alexandria Bay, N. Y., no. 24, p. 385, below.]

"I had a fine view of this superb display at Workington (lat. 54½°) [England] between midnight and 1 o'clock a. m., in a clear and bright starlit sky. The whole sky was filled with the light except a small area in the southeast. I could detect no color except creamy white, the general intensity being, to my mind, at times equal to full moonlight. Curtains of light surrounded a point just east of the zenith, which seemed to mark the 'hub' of the display. The bright star α in Canes Venatici almost exactly marked this point, and filmy sheets of light seemed to dash upward from the southwest and northeast horizons and merge together at this star. The only display I have ever seen to equal this was on February 14, 1907, at Motherwell, in the previous sun-spot maximum period. It was the fact that I could see the great sun-spot train on March 22 without telescopic aid that made me expect and look out for the aurora that night.—W. B. Housman.¹²

"On going out of doors at about 3.15 a. m. [at Whalley (lat. 53½°), England] * * * the aurora was exceedingly fine * * * [and] consisted of about eight broad beams of light, most of which, except the extreme west and north ones, extended to within 5°-10° of the zenith. The lights extended over about 90°-100° from approximately north-northeast to west by north.

"The beams became pale and brilliant again several times, besides constant slighter variations in intensity. On two or three occasions, within about 20 minutes, most of the beams, more than three-quarters, disappeared, leaving one or two longish ones. The color was mostly white, but sometimes reddish in parts, especially nearly due north.

"A curious feature was an oblique band of light, which came and went across near the summits of the vertical beams. I do not think this was a belt of illuminated cirrus, as its brightness seemed to vary independently of the vertical beams, but it is possible it may have been. The lights had diminished considerably by about 3.45 a. m., but had brightened again, though slightly, when I looked out a few minutes later. I do not know what time the display ended."—Lt. Col. Penny.¹³

Two reports were received from vessels on the Atlantic Ocean:

2. Br. S. S. *Iltham Newton*, Captain Fieldgate. Observer H. Bird. P. m. of March 22 and a. m. of March 23. Brilliant display of aurora borealis. Moderate N. W. wind and sea. Latitude 42° 33' N., longitude 51° 00' W. (No exact time given.)

3. Am. S. S. *West Tynes*, Captain Dowling. Observer B. C. Watson, 2d officer.

March 22, 8 p. m. to March 23, 2 a. m. Observed very brilliant northern lights covering entire sky, and at times of deep red color.

Approximate position: 42° 20' N., 62° 30' W.

THE DISPLAY IN NORTH AMERICA.

The best opportunity for widespread observation of this great aurora came to the people in the eastern United States and Canada. The most severe portion of the magnetic storm occurred, conveniently, in the period between 5 or 6 p. m. and 2 a. m., Eastern Standard Time, and the skies were cloudless over a large area. Judging from the European reports, there was no very brilliant phase in this period till about 7:55-8:15, so we really did not miss much of the display during the last two hours of daylight.

⁶ *Terr. Magnet.*, etc., June, 1920, pp. 61-62.

⁷ At Pillkallen, in East Prussia: *Met. Zeitschr.*, May, 1920, 37:130-132, mentions six places in Germany where the aurora was seen, and contains a detailed account of the display from 18^h. 59m. to 20^h. 47m. (G. T. M.), as seen from near Hamburg, and briefer accounts from Potsdam and from Switzerland.

⁸ Abstracted from account by K. Graff, *ibid.*

⁹ *Ibid.*, p. 132.

¹⁰ Translated from *L'Astronomie*, Apr., 1920, p. 154. The whole account covers pp. 153-156, and there are other short descriptions, pp. 156-158.

¹¹ *Nature* (London), Apr. 8, 1920, p. 170.

¹² *Ibid.*, Apr. 15, 1920, p. 200.

¹³ *Ibid.*, Apr. 1, 1920, pp. 137-138.

GEOGRAPHICAL VARIATIONS IN ASPECT.

As usual, the aspect of the aurora varied from place to place and from time to time. This was owing to a number of factors: (1) The curtains do not look the same when viewed from different angles; (2) they are not uniformly bright nor uniformly colored; (3) the aurora is in motion—the whole display rotates westward as the earth turns under the more or less stationary magnetic field, the curtains move southward, their folds and other streamers unfurl eastward and westward and their lights flash upward individually and wave upward in unison.

In spite of these movements, the occurrence of periods of marked intensification of the lights, wherever they happen to be, is shown in the descriptions; and thus permits of an attempt to map the positions of particular auroral curtains at certain times. The possibility of such mapping is rendered simple by the fact that the bases are at practically the same altitude—about 100 kilometers. But its actual accomplishment is difficult without reports of angular heights of the under apexes of the brighter arches at particular times. Fortunately, there were enough of such angular heights estimated, and enough reports from places directly under such curtains to determine their positions at times when the display of March 22–23 was unusually bright.

Before discussing further the geography of this aurora, it would be well to introduce some of the accounts themselves to show how the features seen in one part of the sky from one place are visible in another part of the sky from another locality.

AN AURORAL CROSS-SECTION VIEWED FROM SOUTH TO NORTH.

The brilliant curtains which at about 10 and 11:10 p. m. (75th mer. time) were directly overhead, respectively, at about latitudes 37° and 38° across central Virginia, were described as follows at selected places south and north of them:

4. *Bradentown, Fla., lat. $27\frac{1}{2}^{\circ}$.*—* * * As we drove in our front gate * * * we noticed the bright glow over a large area in the northern sky. At first we thought it must be the reflection from a fire but * * * the glow was too pink. * * * A dark wave passing rapidly across the glowing surface, the light coming out again immediately following the dark wave, caused me to recognize it as an aurora. * * * The dark waves in this instance passed from right to left (east to west) three or four times while we were watching it. * * * In the glowing area I noticed several faint streaks shooting in or across it from south to north. It was about 10:15 p. m. [90th mer. time] when we first noticed it and after putting up the horse and going to the house I could still see a faint glow.—*F. H. Braymer.*

5. *Leesburg, Ga., lat. $31\frac{1}{2}^{\circ}$.*—A faint aurora was observed between 9:15 and 10:15 p. m., having a reddish base with a few streamers projecting from it. Due to the presence of alto-cumulus and strato-cumulus clouds at this time very little of the aurora could be seen. First seen about 9:15 p. m. and entirely disappeared at 10:15 p. m.

6. *Augusta, Ga., lat. $33\frac{1}{2}^{\circ}$.*—The aurora first appeared in a direction NNE. as a luminous white streak along the horizon. It rapidly grew brighter in the north and threw out streamers which had the appearance of the beams from a giant searchlight. These beams moved across the sky in a northerly direction and reached an altitude of something over 45° . The aurora gradually turned from white to yellow, then to pink, and finally to a deep red, which slowly faded out. The display began at 9:45 p. m. and ended at 10:10 p. m.

The Western Union and Postal Telegraph companies reported all lines affected practically all day, the trouble being worse during time of the display and on lines running north and west.—*Louis A. Sledge.*

7. *Columbia, S. C., lat. 34° .*—An auroral display was observed in the north from dark to about midnight of the 23d. The arch was not particularly noticeable until about 9 p. m., except a rim of hazy, whitish light in a circle above a dark bank, rising about 10° above the northern horizon. Toward 9 p. m. the white light assumed a reddish hue, and occasionally reddish streamers * * * [5 to 10 times

as long as wide] would shoot above the dark bank and move toward the east, finally dissipating; this continued until about 9:45 p. m., when the display was at a maximum, and the general light effects were distinctly reddish; after 10 p. m. the light gradually changed to whitish, with occasional flickerings. The aurora was last observed about midnight, when the white circle was very indistinct. * * *

8. *Wilmington, N. C., lat. $34\frac{1}{2}^{\circ}$.*—Auroral display observed from 7:15 p. m. until dawn of the 23d. It had the appearance of a faint, misty light extending about 60° , centered along the northern horizon, its average altitude being about 25° with occasional thin, faint shafts of light reaching an altitude of 50° to 60° . Its color was mostly a yellow tint but for a short time it had a faint rosy hue and toward morning took on a greenish tint.

9. *Greenville, S. C., lat. $34\frac{1}{2}^{\circ}$.*—At about 10:15 p. m. a very bright and spectacular ribbon of light, or streamer, on the extreme right of the display, varying in color from a violet to greenish outstanding, extended nearly to the zenith, the other lights generally of a golden glow gradually receding to the horizon. The entire distance along the horizon in the northern sky was about 60° . The brightest was over at 10:30 p. m., after which there was more or less a steady glow of a golden appearance near the horizon into the later hours of the night.—*Prof. M. E. Brockman.*

10. *Charlotte, N. C., lat. $35\frac{1}{2}^{\circ}$.*—* * * As soon as the twilight disappeared, the aurora was seen in full brilliancy, extending around the northern horizon for 45° , with its center directly under the pole star and extending up to the Little and Big Dippers, which were nearly overhead at midnight.

Streamers of white and pink-blue light could be easily traced, wavering like moving pictures on the sky. The aurora was the finest about 45° above the horizon. Its upper limit was a great arc, which had its highest point near the pole star, curving gradually to the horizon $22\frac{1}{2}^{\circ}$ on each side of the north point. [The display was visible till near dawn.]

11. *Asheville, N. C., lat. $35\frac{1}{2}^{\circ}$.*—A brilliant aurora was * * * first seen about 10 p. m. and continued until nearly morning [of the 23d]. * * * Streamers extended upward nearly to the zenith and * * * the colors were brilliant.

12. *Wyerlyville, Va., lat. 37° .*—* * * When first seen 8 p. m. the entire heavens seemed alight, many people thinking a large fire was in progress. Colors were mostly golden, yellow, and red with varied combinations. * * * In the north, below the illumination, an apparent wall of dark cloud(?) was observed. From a little west of north waving streamers shot across the sky well to the south, while in the north and to the northeast shimmering undulating waves of golden, yellow, red curtains would flash beyond the zenith.—*J. S. Widmeyer.*

13. *Norfolk, Va., lat. $36\frac{1}{2}^{\circ}$.*—* * * At 8 p. m. a faint arc with an altitude of about 30° extending from northwest to northeast, and of a light green color, was observed. The background was unusually black. No vibrations or streamers were observed until 9:55 p. m., when suddenly there appeared streamers out of the whole arc which extended nearly to the zenith. The color of the streamers was light green, except in the northeast where the streamers were of a rose hue. At 10:05 p. m. the streamers disappeared and the background became brighter, but the arc was still visible at 10:45 p. m.

The appearance of a curtain overhead is described in parts of most of the longer accounts published below. As the curtain nears the zenith, the converging rays of its folds (really almost parallel, but converging in the distance) seem to shoot at a target making the auroral corona at the "magnetic zenith" a few degrees south of the true zenith. Almost simultaneously from the eastern and western horizons the light rises in great serpentine waves or spirals up which meet with a flood of light at the corona. To illustrate here are descriptions of curtains overhead as seen at Gloucester, Mass., and New Haven, Conn.:

14. *Gloucester, Mass.*—* * * The most striking effect was that of irregularly curved bands of light, sometimes 50° in length, passing near the zenith, which would be strongly luminous for a few seconds and then a faint illumination would persist for several minutes. This was not due to persistence of vision, and the whole faintly luminous area would slowly drift toward the east, while occasionally new areas would flash up, the curvatures of which would be nearly parallel to the first. This occurred several times and once four areas were noticed simultaneously with the same general curvatures. The faint luminosity did not flicker but gradually disappeared, unless, as occasionally happened, it would again be illuminated, sometimes with one edge more brilliantly lighted than the rest, giving an edged curtain effect. The drift of the faint luminosity was distinctly toward the east by comparing it with stars, and immediately after the discharge its intensity seemed about that of the galaxy. Estimating the drift

as about 5° in 5 minutes and assuming the disturbance at 60 miles up would indicate a velocity of the ionized air of about 350 miles per hour.—*H. G. Dorsey.*

15. *New Haven, Conn.*—* * * At 10:00 p. m. * * * [a bright band] extended from near the eastern horizon in a long uniform curve to a point well to the southward of the zenith. When first observed its width was 5° or 6°, but gradually became narrower and as it did so took on a twisted appearance. * * *

Lat. 39°, Chevy Chase, D. C.—In the southern sky the lowest arch in broken form came within about 30° of the horizon at its under apex at 10:05 p. m.—*C. F. Brooks.* (For remainder of account see No. 18 below.)

16. *Jericho, Vt., Lat. 44°.*—The [display] was unusually brilliant, auroral rays extending low down clear around the horizon, centering overhead, center somewhat south of vertical, farther south than I ever saw it before. Pulsations of the rays were often unusually vigorous. The most remarkable feature to me was the great distance the aurora extended to the south, clear down almost to the horizon, especially in the southeast. There was an unusual brilliance of the rays and nebulous light far to the southeast in the evening (for some time), exact time not noted.—*W. A. Bentley.*

THE AURORA IN MOTION.

If these descriptions of the same curtain as seen from different latitudes were merged into a single account, and if that section describing the display from Florida to Virginia were repeated and woven into the account for Virginia to Vermont, we should have in its essential features a description of the display at a single place, such as Washington, D. C., as the curtains kept forming or appearing in the north, and traveled southward. In many of the descriptions the time-interval between the arrival of an arch at a height of 45° in the north till it reaches the magnetic zenith, where it forms a corona, is a matter of about a quarter of an hour or less. This indicates a southward speed of 400 to 1,000 kilometers per hour. For some specific details as to the movement of arches note the next to last paragraph in the account of the display at Wichita, Kans. (17), and the description of the display from 7:59 to 8:18 p. m. at Washington, D. C., (18).

As the curtains fade away in the south new ones come out of the north. At times during the display of March 22, five to ten curtains were distinguishable at the same time. (See the following descriptions).

17. *Wichita, Kans.*—A very beautiful display of the Aurora Borealis or Northern Lights, was observable in Wichita on Monday evening. While the display was for the most part rather faint, a great variety of auroral forms developed at one time or another; in particular a specimen of the so-called elliptical arc. The aurora was at first distinguished at 7:40 p. m., according to observations by Lincoln La Paz, at Fairmount College, as cloudlike masses of excessively faint light in the northern sky, and continued in a greater or less degree until after midnight. At 8:50 the auroral light became intensified in a long band stretching from northwest to the east point, and bright parallel rays of white light rising from this band made their appearance. By 9:04 the band had become a great elliptical arc, faintly greenish in hue, and the parallel rays were noticeably reddish near their summits. This was by far the most interesting phase of the spectacle, the arc expanding across the heavens like a wave on the surface of a pool until it passed the zenith and extended into the southern half of the sky.

After 9:10 the display began to diminish in brightness, but faintly red and green rays, with here and there a shaft of white light resembling a dim searchlight beam, endured 8 or 10 minutes longer. At its maximum the auroral light caused a noticeable illumination of the north walls of houses and occasioned a great deal of comment on the part of those who were fortunate enough to observe it. It is possible that the display seen in Wichita is only the southern fringe of such a nation-wide aurora as appeared in March, 1918.—*Wichita Eagle.*

The long band of intensified auroral light noted at 8:50 p. m. was, strictly speaking, a double arch [with ends and junction 11° above the horizon] * * *. The altitudes and bearings of the end points of the arches and of their point of intersection were determined using a transit from which the object glass and eyepiece had been removed; and the measures show that the junction of the arches was nearly on the magnetic meridian of this locality.

After 8:50 the aurora grew steadily brighter reaching a maximum at 9:04. At this time the double arch had been replaced by a single elliptical arc some 15° broad along the magnetic meridian and extend-

ing from N. 30° W. to N. 90° E. The lower sharply defined boundary of the arc remained sensibly stationary at an altitude of 10°, but the upper edge was soon observed to be swelling toward the zenith and about 9:06 it was seen to pass over the Dipper. The velocity of its expansion was such that it spread from Alpha to Beta Ursae Majoris in 30 seconds; however, the diffuseness of the wave front was such that the moments of its transit over these stars were uncertain to the extent of 2 or 3 seconds. At the moment that the front of the arc passed through the zenith it was seen projected on the sky as an appreciably straight line meeting the horizon in the points S. 80° E. and N. 80° W.; later as the arc-front descended into the southern sky it became concave to the south. At the time of maximum extent the auroral illumination spread along the magnetic meridian from an altitude of 12° in the northern sky to a point perhaps 20° south of the zenith. It is worth noting that the change in the direction of curvature mentioned above is what one would expect to observe during the passage through his zenith of the luminous plane whose south edge was approximately straight and all points of which were at about the same height above the earth's surface.

While the coloring of the aurora under discussion was far less intense than that of the one observed here in March, 1918, the variety of faint hues, the constantly changing forms, and above all the beauty of the expanding wave of auroral light lent to it an interest far greater than that of the earlier display.—*Lincoln La Paz (Physics Laboratory, Fairmont College).*

The following detailed descriptions from Chevy Chase, D. C., Hyattsville (10 miles east), and Cheltenham (20 miles southeast), Md., are presented here, as an example, to show the sequence of auroral events as visible from (essentially) one place:

18. *Chevy Chase, Washington, D. C.*—This great display was characterized by the following features (1) Unusual extent covering more than half of the sky most of the time, and over nine-tenths of it once; (2) softness of the light, which, in smooth whitish sheets, covered the sky with varying brightness, just as would cirro-nebula cloud of varying density; (3) relative shortness of the streamers, they were not hard in outline most of the time, as is usually the case, nor did they extend high above their respective arches; (4) general brilliance and occasional color, mostly crimson.

This display evidently started during the daytime, * * * for it covered much of the northern sky when first seen at dusk. At 7:34 p. m., when I first saw it, the northern sky up to the Pole Star was covered with a smooth, irregular whitish light from WNW. to ENE., giving more or less the appearance of smooth cirro-stratus clouds, with some holes in it. It had a general arch-like form. At 7:35 there was a temporary development of streamers in the north and east. At 7:43 the smooth, diffuse light had risen to the zenith.

BRIGHT PHASE, 7:43-8:24 P. M. (75TH MER. TIME).

7:43, streamers tipped at their lower limits by red light. Rapid lateral movement in the streamers.

7:48, the sharpest arch in the north was 10° above the horizon, leaving a dark segment immediately below it.

7:51, the arch in the northern sky took on the appearances of a hazily seen, bright curtain.

7:53, in the northwestern sky there were well-marked waves as if from the west in the diffuse light. The waves were apparently stationary and looked much like waves seen at times in stratiform clouds, though the sky was evidently cloudless at this time. These waves were most marked in the WNW. at about 20° above the horizon.

7:54, a number of streamers became crimson.

7:56, fair-sized patches of light in NE. and N. The auroral lights covered the northern half of the sky and some of the sky a little south of east.

7:57, general intensification of streamers.

7:59, for the first time a streamer was noted, in the dark segment, reaching down to the northern horizon. The top of the bright arch was 80° up in the north. Between the upper arch and the lower one the sky was covered with auroral cloud, more or less irregular in brightness.

8:00, the arch in the north was irregular on its underside, but the general elevation of the arched part was about 12° in the north. Edge of the upper arch reached Jupiter (about 17° south of the zenith).

8:01, the center of the arch passed Jupiter.

8:02, the arch reached Orion's belt.

8:03, the arch reached the middle of Orion's sword, fading out.

8:04, new intensification of streamers. Relatively smooth arch up to 12° in north. New wave of light reached Jupiter.

8:05, new wave of light reached Procyon (about 30° south of east-west line).

8:06, new wave of light reached Orion's belt.

8:07, new wave of light reached Saturn (about 20° south of east-west line) and top of Orion's sword. New curtain and dancers low in north.

8:08, crimson streamers in east. Five arches in northern sky.
 8:09, light fading out at tip of Orion's sword. Faint belt reached Sirius (about 40° south of east-west line through zenith).
 8:10, crimson light from eastern horizon up to zenith. Renewed brilliance in streamers. Dancing in north and east.
 8:12, another belt of light reached Sirius. Crimson in east fading.
 8:13, irregular-topped, whitish belt of light nearly overhead.
 8:14, crimson light in east and west and overhead.
 8:15, new belt of light reached Saturn. Streamers brightening again, streamers short.
 8:16, new belt of light to knees of Orion.
 8:18, still another belt to Jupiter; that mentioned (8:16) last, gone.
 8:19, new streamer display, very much like more or less irregularly-lighted narrow belts of cirrus east-west having sharp crosslines of falling snow.
 8:21, half of corona.
 8:22, first flickering.
 8:24, display best so far.

RELATIVELY QUIESCENT PHASE, 8:28 TO 10 P. M.

8:28, much fainter flickers.
 8:31, diffuse light overhead, half of sky particularly bright in NNW.-NNE., 15° to 60° up.
 8:40, lights all over north half of sky, comparatively faint (relative to earlier brilliance).
 8:50, lights over northern half of sky generally fainter except for a nearly perfect arch in the north.
 8:51, temporary increase in brightness with some streamers.
 9:20, arch in the north, 30° up, becoming double. Streamers through Jupiter and 10° farther toward the southeast. Display generally as at 8:51.
 9:33, display knotty again.
 (9:35-10:00, details not observed.)

THE CLIMAX, 10:01 TO 10:20 P. M.

10:01, suddenly getting brighter.
 10:05, crimson, yellow, green, and blue lights unfurled in various parts of the sky. A brilliant piece in the NNE. showed all the colors of the spectrum for about a minute, the red being down. Round the magnetic zenith, radiating sheafs of brilliant red and green and blue appeared, completing the auroral corona. In the southern sky the lowest arch in broken form came within about 30° of the horizon at its under apex. Although a little of the horizon could not be seen, it appeared that the auroral lights extended to the horizon in the southeast and southwest. Practically the whole sky was pulsating with rising waves of light. A wave would take about a second to go from the Pole Star to the zenith.
 10:05-10:12, an unusually bright crimson patch occupied the sky in the NNW. to a considerable height (about 60°).
 10:15, the display had faded some. The flickering continued.
 10:21, the streamers, the corona, and the flickering continued, the display still covering about three-fourths of the sky.
 10:29, the display was again slightly on the wane.
 10:53, the arch in the north was well defined and lower than before. The corona, the streamers, and the flashing of the lights were still present.
 11:11, six arches of light in the north, not continuous. Three-fourths of sky affected by the aurora. Spots in the south visible only on flashes. Display still flashing. Red base to lowest arch in NNE.
 11:12, two-thirds of corona again.
 11:17, general crimson in N-NNE. Spectral colors on lowest arch, red at bottom.
 11:20, bright corona, with white sheaf extending southeastward.
 11:21, crimson in NNE. to NW. and W.
 11:25, southern half of corona crimson for a minute. Much crimson in north high up, especially in NW. (a streamer).
 11:27, flashing white light behind the crimson streamer. Display fainter.
 11:58, height of underside of center of arch about 10° above northern horizon. Some streamers. Aurora over two-thirds of sky flashing moderately. Red on edge in northeast. Three-quarters of a corona.
 11:59, brightening again in northeast.
 12:06 a. m., arch in north broken up. Most of it bright whitish. Two-thirds of a corona.
 12:17, brightening.
 12:23, still bright. Two irregular arches in north, not as high as before.
 12:30, two arches in west, bright. Part of corona still. Flashing spots in the south down to 45° or 60° above southern horizon.
 [Mr. Fairfax Naulty, over the telephone, stated that he had watched the display for the rest of the night, and that about 2 a. m. there had been a maximum of brightness equaling, perhaps, that of 10 p. m.]
 The time used in this description is Naval Observatory 75th meridian time. My watch was set at noon on the 22d and checked at noon on the 23d by the telegraphed ticks.—Charles F. Brooks.

19. *Chevy Chase, Washington, D. C.*—* * * As late as 3:30 a. m. the aurora was still making a fine display, though not nearly as spectacular as between 10 and 11.—C. Waters.

20. *Hyattsville, Md.*—The following [is a] copy of my notes taken March 22, about 10:30 p. m.: "First noticed dull glow, like before moonrise, from NE. to NW. with darker area lower down, about 7:30. Before 8 a good many changing streamers seen. About 7:50 to 8 was curtainlike with lower edge about 20° above northern horizon and light up to zenith."

"I was out again from 9:40 till after 10. There were at first faint zones of light from NW. to SE. and light playing back and forth on these like faint broad searchlight beams, but broken and irregular. About 9:50 there was a most brilliant waving curtainlike effect in the north, waving and changing like a rain of light all along the northern sky, with very dark below this irregular arch. About 10 this effect had spread over the whole sky. * * *"—J. B. S. Norton.

21. *Cheltenham, Md.*—The aurora was visible soon after sunset, but was first noticed by the writer at 8h 05m standard time. At 8h 10m a display of rays developed, proceeding from a bright band low in the northern horizon some 45° in extent. * * * The rays [at 8h 10m.] were visible from a point in the western horizon a few degrees (5°-10°) north of the new moon (azimuth from S=88°) to a few degrees in the eastern horizon east of Arcturus (azimuth=-76°.0), and apparently converged to a few degrees north of planet Jupiter (azimuth 26.5 and altitude 68°.5). There was a conspicuously rosy colored ray in the east. The rays lasted for about 5 minutes. The boundary of the illuminated area was parabolic in form. The ray display was followed by a general diffused glow.

At 9h 55m the diffused glow was bounded by a lighter arc extending from near the planet Mars in the east to some 15° south of Jupiter toward the west. At 10h 00m the rays were developed on a grand scale, and seemed to emanate from an altitude of 20° in the north and 30° in the south. The rays converged to a point half way between the star Regulus and the planet Saturn (alt.=62°, 5; az.=-11°.0). This ray display lasted 15 minutes, and then flickering movements became conspicuous. There was a rosy glow in the west. At 10h 40m nearly the entire sky was illuminated. At 10h 45m rays were visible in the north. Rays were again strikingly conspicuous from 11h 04m to 11h 15m; they converged from all directions to a point near Saturn (alt.=62°; az.=-12°.5) and were followed by flickering movements. Observations ceased at midnight.—Geo. Hartnell, Magnetic Observer U. S. Coast and Geodetic Survey.¹⁴

GEOGRAPHY OF THE AURORA.

Farther north, the display at dark had already reached into the sky south of the zenith. From all the accounts, especially from those which gave angular measurements or estimates of the heights of arches in the northern or southern sky at particular times, figure 1 has been constructed to show the positions of the brighter auroral curtains during the display. By 7:45 there were enough observers to make it possible to locate the position of the principal bright arch, across New England, central New York, and the Great Lakes. Another arch was observed some 200 kilometers north of Eastport, Me. (22).

At 8:15 when the whole display had reached one of its most brilliant phases, the southern arch had reached as far south as Richmond, Va., and there were pronounced general arches each with one or more curtains crossing the Atlantic coast district at about latitudes 39°, 42°, 46°, and 49°. For the relatively quiescent phase that followed no attempt has been made to locate the curtains. At the time of greatest brilliance of the aurora in the eastern United States, from about 10 to 10:05 the southernmost arch seems to have been at latitude 36°, and the brightest curtains (Atlantic seaboard) at latitudes 37°, 39°, 41°, 42°, 44°, and 47°. That at 41° seems to have been the most brilliant. During the bright period at about 11:10 the principal curtains seem to have been at latitudes 38°, 39°, 41°, 42°, and 47°.

The positions of the curtains at 8:15 and 10:05 are shown on the map, figure 1, as are also the 74 numbered locations of the places from which descriptions of the aurora are being published in this article. The dots represent locations of other places from which information about the aurora was received.

¹⁴ Excerpted from *Terr. Magnet.*, etc., June, 1920, pp. 59-60.

Mr. Dier informs me aurora always interferes with telegraphic conditions on east and west lines but not on north and south.—*J. P. Henderson, Dominion Astronomical Observatory.*

24. *Alexandria Bay, N. Y.*—After an extended period of apparent retirement, the aurora shone with a remarkable brilliancy on the evening of March 22d from about 7:30 o'clock until long past midnight which at the last observation appeared as an evenly distributed green glow almost over the entire sky.

The leading feature of this display and that which caused considerable comment was that the northern sky was dark except for a few stars shining hazily, but to the south and east and west from about 40° above the horizon to the zenith beautiful streamers of greenish hue flashed upwards where they formed a crown overhead. Later these streamers began coming up out of the northern sky and then words pale at the description. Still later the lights hung like a huge curtain in the northern skies constantly moving and shifting and with the many tints of the rainbow, but at all times green predominating. At one time the formation was that of a huge hook composed of yellow greenish light in rapid movement.

The plane of the lower limit of this aurora was well defined just as the plane of condensation appears in the cumulus cloud region on a warm summer day. The motion of the light was seemingly upwards as is observed usually in all displays.—*Douglas F. Manning.*

25. *Alpena, Mich.*—An auroral display of unusual brilliancy developed at 6:45 of the 22d and continued with varying splendor until just before daylight of the 23d. When it was first observed, it was a steady glow covering the entire southern sky, 270° through south to 90° azimuth. That part passing from east to west through zenith was particularly bright greenish white. In a few minutes it faded away near the southern horizon and the display became active north of the zenith and shortly the aurora covered the entire heavens. The waves of light had a greater tendency to progress rapidly in a lateral movement first one way and then another, instead of up and down. In the eastern and western skies, between 7 and 8 p. m., there was a pinkish cast to the display.—*F. Jermin.*

26. *Escanaba.*—A brilliant aurora was observed from 7:15 p. m. to 11 p. m. of the 22d. The first appearance was that of numerous streamers in the northern sky which converged at the zenith. By 8:30 p. m. the phenomenon assumed a more curtain-like appearance, investing the southern heavens as well as the northern. The greatest activity and brilliancy, however, prevailed in the northern quarters. The predominant color was greenish-yellow.

27. *Marquette, Mich., March 22.*—Aurora was first seen in north at 7:15 p. m.; brightest at 9:20 p. m.; last seen at 10:45 p. m.; azimuth from 1° to 360°; altitude, 90°. This aurora consisted of merry dancers and great fields of light that pulsed and waved from the east to the west. The color was ever-changing, and varied from a small amount of silver-white through gray to small areas of bright red to very large areas of dark red and almost black.

28. *Houghton.*—An usually fine aurora was observed on the evening of the 22d, from 7 p. m. to 10:30 p. m. The form was constantly changing, but during most of the time there appeared to be a nucleus, at times a vortex just south of the zenith, and from this streamers radiated in all directions. The colors ranged from white and yellow to purple and pink.

29. *Devils Lake, N. Dak., March 22.*—A bright aurora * * * was observed about 8:30 p. m. The arch was overhead.

30. *Hoosick Falls, N. Y.*—Except for intervals of a few minutes, I observed the display from 7:45 p. m. (eastern standard time) until 11:30. In the curtain form a very bright single ray ran directly from the zenith approximately 20° to the east and the same angular distance to the west. Extending about 8° in angular width toward the south from along the whole length of this ray there was a bright web of light, which resembled a curtain hanging in folds but lying horizontally instead of hanging vertically. Along the serrated southern edge of this web the light was much brighter at the place where the curtain had the appearance of doubling over upon itself. The whole formation was quite steady and would last five or six seconds without appreciable change; then, becoming unsteady, would quickly disappear and rapidly reappear in the same form, but slightly different as to details, chiefly length. The curtain formation was very bright when the sky was first observed at 7:45 p. m., and its brightness increased until a few minutes after 8 p. m., at which time it was so bright that the attention of everyone out of doors was at once attracted to the zenith. As observed here, this was the brightest, as well as the steadiest part of the whole display. During the next half hour or so the curtain faded rapidly until it was seen no more.

While the curtain display was in progress unsteady rays and shafts of light were appearing here and there, chiefly to the east and to the west, and they appeared to converge at a point located about 10° to the southeast of the zenith. As the curtain display faded, the converging rays became brighter. About the time the curtain finally disappeared these rays presented a curiously solid look to the eye, as if the hand was to be extended sufficiently high. Some of the rays appeared like shafts of light from a searchlight. This appearance was not noticed later. The rays were constantly in slow motion, some-

times a large portion of the sky being covered by them, and at other times only a few wisps of light being visible. Shortly before 11 p. m., the focal point seemed perhaps a trifle closer to the zenith than it did in the earlier part of the evening.

At intervals, while the ray display was in progress but apparently brighter when the rays were weaker, there were noticed diffused circular or oval spots of light toward the northeast at an average elevation of about 30°. These spots would persist for a half minute or so, and then would fade away without changing position.

By 10:30 p. m. the rays had much weakened, and it was supposed that the display was chiefly over. But at about 11 p. m. the rays brightened, increased in number, and became violently unsteady. Then, for 15 minutes or so, there followed the whirl form of display, which was perhaps the most beautiful part of the entire phenomenon. The sky overhead was filled with waves of light moving with great speed, crossing and intercrossing one another in all directions. The light waves appeared as if they were being driven by conflicting and interacting currents; and the sight at once suggested to the mind a view of the movements of snowflakes as seen above a city street during a driving snowstorm.

As if exhausted by this outburst, the entire auroral display weakened, and by 11:30 p. m. had become comparatively faint.

In color, the display overhead was whitish yellow, with a greenish tint; to the northward the greenish color was stronger; while toward the south there were slight touches of a pinkish hue. These differences persisted throughout the evening, although the whole display became slightly more pinkish as time went on. In addition, there were observed, now and then, a few very fleeting rays which appeared to have a reddish tinge.—*R. H. McEachron.*

31. *Albany, N. Y.*—* * * From my north windows I get a good view of the sky from about 20° or 25° east of north to the east, and I could look up to the zenith fairly well. At 12:15 a. m. Tuesday, March 23, on looking out of my northern windows I saw broad bands of silvery light welling up (I can choose no better word) approximately from NNE. to NE., which I at once recognized as auroral. The sky was cloudless; there was no moon, and the stars shone brightly. The light was silvery, devoid of any color, and there were no sharply defined rays nor any transient flashes. The appearance was that of great waving streamers, or broad ribbons somewhat resembling a searchlight, but without sharply defined edges, extending well to the zenith and what impressed me most, and seemed to me the most remarkable and unusual, was the appearance of the light in seeming to well upward as if ejected or projected and not as merely raying upward, and also and particularly the waving of the broad streamers, or banners. I had never seen anything of this nature before and it filled me with awe. * * * From my south windows a somewhat similar appearance presented. By 12:45 it had largely disappeared, and on looking out once or twice afterwards I saw no further display.—*W. G. Tucker.*

32. *Syracuse, N. Y.*—* * * Toward 9 p. m. I noticed folds or curtains in the east and toward the horizon beautifully colored tints. At 9:30 I observed that Sirius was well inside of the display, and the show was going on with unabated vigor. Again at 3:30 a. m. it was still going, and workmen observed it at 4:30. I didn't see it so well the next night, but it was felt by instruments. An interesting feature on the 22d was the playing of a most powerful Army searchlight on the sky during the auroral display. There was no possibility of mistaking one for the other, as they were seen side by side.—*E. D. Roe, jr.*

33. *York, N. Y.*—Display first noticed about 8 p. m. Luminous clouds seemed to form near the zenith and streamers to lengthen downward (although motion of light in them was upward) in all directions, first to north and west, then to east and south. The coloring was varied and distinct—red, pink, violet, and green, as well as an abundance of bluish white streamers. After covering nearly the whole sky for some time, with the exception of that portion less than about 10° from the horizon, the aurora subsided and before 9 p. m. only a diffuse glow in the north remained. About 10 p. m. renewed activity was noted. Swirling, cloud-like tongues of white fire rushed toward the zenith from the north and then from all points of the compass. Many times the corona appeared, faded, and reappeared. No coloring was evident at this time save a greenish tinge to certain patches in the north. The position of the corona, as sighted at the time (10:30 p. m.) and afterwards measured, was about 13° south-southwest of the zenith. At 10:15 p. m. there were two arches in the north—the apex of one being about 15° above the horizon and that of the other about 20°. These lighted up and faded several times, the illumination seeming to proceed from west to east in opposite direction to my previous observations on these northern arches. At times the corona showed a dark center and again it appeared as dense white cloud. About 11:30 the light became more diffuse, and at 11:45 only an unusual brightness in the north remained.—*Milroy N. Stewart*, cooperative observer.

34. *Saginaw.*—The aurora was observed at 6:35 p. m., continuing all night of the 23d into the early hours of the 24d. It died away about 4 a. m. of the 23d. It was first noticed as a colored arc, red to faint green from due northwest to east-northeast up to 5° north of Polaris, and streamers going up to 2° south of the zenith, meeting like the ribs of an umbrella. The whole cloud form followed at 8

p. m., covering three-quarters of the sky, only the southwest and west below Orion being free. There were comet-like heads appearing and disappearing, the waving curtains, the ascending smoke effect, and the rose-tinted clouds. At 10 p. m. there was a brilliant red to green arc about 10° above the horizon at the top, from due northwest to due northeast. At 10:15 p. m. there was a brilliant mantle meeting in a nebula-like head 2° south of the zenith. This corkscrew-like cloud flashed, appeared and disappeared. It would drift from the northwest, fade and reappear in the same position. At 11 p. m. a uniform white cloud with streamers and white mantles covered two-thirds of the sky. At times during the evening there were irregular clouds with rose-colored fringes at the bottom. The streamers and mantle took the form of an immense number of parallel white threads with strange dark lines at intervals within. The smoke effect seemed to be from lights running rapidly through cloud forms, giving the effect of smoke rising at enormous speed. The light of the display was often as powerful as a three-quarters moon.

35. *Ludington, Mich.*—Remarkable and brilliant aurora * * * beginning at about 6:45 p. m. and continuing to about 4:30 a. m. Most of the time the display consisted of bands and sheets of streamers, mainly whitish, mostly over the northern half of the sky, but in some degree also in the south, which extended upward and converged in a crown near the zenith. The crown was very pronounced at 7 p. m. At 7:12 there was an irregular arch with patches of various colors in the north. At 7:25 a diffused yellowish light covered most of the sky, increasing toward an arch of the same color in the south, beneath which the sky was dark blue. At 8:40 p. m. several whitish bands spanned the sky, through the termini turning toward the north. From 8:55 to 9:10 the crown was again pronounced and there were many streamers. At 10:20 p. m. and thereafter the display was less pronounced. At times during the evening long brightly colored streaks, one or two at a time, several vertical and several arched, would appear and drift across the sky. Not much flashing occurred before midnight, nor did the streamers in general move much to the eastward or westward. From about 2 a. m. to 3:30 a. m. there was remarkable flashing. The zenith crown was again distinct, and from all quarters of the sky, but mostly from the northern half, whitish sheets and streaks shot upward toward the crown. The spectacle was very impressive, the whole vault appearing to combine in the display. * * *—*C. H. Eshelman.*

36. *Westwood, Mass.*—* * * [at 7:45 p. m. the aurora] consisted of repeated folds of the "hanging curtain" type. The lower brilliant margin of the curtains reached an altitude about that of Polaris at 7:45 to 7:55, and the stronger folds or "pillars" extended to beyond the zenith. In addition to some wandering of the pillars to and fro, there was an expansion of the principal central fold of the curtain, so that pillars on the eastern edge were, on the whole, moving east and those on the western edge west. One or two more distant folds in the northeast were at this time exceedingly brilliant and the whole was remarkably clear-cut, in contrast with the blurring of the details which [shortly succeeded].

The entire arch rose rapidly to the zenith and at about 7:55 and 8:05 its advance pillars, being seen end-on, gave repeatedly the most brilliant coronas I have ever witnessed. At about 7:55 the vanishing point of lines of light parallel with the dipping needle was observed to be about 2° W. of Jupiter and 2° to 3° N. of same. Ten minutes later the motion of the planet had carried it on until the coronal apex was 1° E. of Jupiter and 2° to 3° N. of it.

From 8:15 to 8:30, when the first and most brilliant set of curtains had passed south of the zenith, other not quite so bright series of curtains and broken arches had succeeded until the whole sky from 10° above the northern horizon to 20° above the southern was filled with patches of variously moving luminosity, but blurred as if seen through a lower phosphorescent film which dimmed the stars (previously standing out brightly on a cloudless sky). This film was not simply an ordinary cirro-stratus cloud, for it shone with a diffused glow of its own which illuminated the landscape with a peculiar shadowless light coming from every direction. There was continuous motion but it was ill-defined on account of the general obscuration by luminous haze. Others who were with me spoke of colors, but I saw only the prevailing greenish white.

At 9:30 the appearance had changed to that of serpentine bands extending in a generally transverse, i. e., east-to-west, direction. These came and went, flashing out briefly in the midst of the same indefinite general illumination which extended over a large part of the sky. Coronas were not evident, although the part of the sky where they had previously been, was still filled with light.

From 10 to 10:10 bright belts (N. to S.) were seen in the east, and, as it were, quivering flames southeast which, after 10 minutes, rose to the zenith.

At 10:20 a bright band (20° altitude) extended E. to W. in the north and bright cloud-like bands (N. to S.) in the east. General distribution of irregular patches and serpentine bands constantly quivering.

Shortly after 11 o'clock bright patches 40° to 50° broad were most evident in the east and west. The eastern one had upwardly-curving bands on its southern edge and flickered, but not through great stretches.

The western mass continually cast up most vivaciously flickering "flames" which ascended upward and southward through 50° or 60° fading away to be instantly renewed in perpetual succession. This lasted a long time.

Four stages may be specially noted in this display:

1. The hanging curtains, pillars, and coronas, all sharply defined, the pillars moving to and fro, but not rapidly.

2. General luminous haze and indefinite mixed forms, continually changing, but ill-defined. Sky covered with luminosity from 10° above N. horizon to 20° above S.

3. Same, but more distinct bands extending in numerous serpentine lines in a general E. to W. direction.

4. Broad bright masses, curved streamers and flickering flames.—*Frank W. Very* (Westwood Astrophysical Observatory).

37. *Concord, Mass.*—The following is a copy of notes made on the display:

March 22. Fine display of aurora this evening. First noted at 7:05 p. m. when streamers and patches of pale greenish-yellow light appeared at intervals covering the entire northern and eastern heavens. At 8 o'clock a waving "curtain"-effect appeared in the west and northwest and this gradually gave way to fine, narrow yellowish streamers rising to the zenith with nearly the entire southern sky to within 30° of the southern horizon, pulsing with ever-changing "puffs" of yellow light. At this time no streamers or light of any description was visible in the northern sky. At 10 p. m. faint streamers came out of the NW. and rose to an altitude of 80°. Sky clear all the evening except for a few C. S. or A. S. clouds along the western horizon.

38. *South Hadley, Mass.*—[There were] * * * beautiful draperies or scrolls in the east and a lovely converging effect of streamers, like a shower bouquet. Point of convergence close to Jupiter between 7:30 and 8, when brightness was maximum. Tried to obtain spectrum with small (Schmidt & Hensch) direct-vision spectroscope. Saw four lines (or bands) not bright enough to get color. Twice while looking a sharp bright red line flashed out; heard the "Oh's" of students at the same time. There was a good deal of pink in the west and at points overhead. The draperies were white or greenish. Display lasted on and off all night.—*E. R. Laird.*

39. *Binghamton, N. Y., March 22-23.*—The most brilliant auroral display ever witnessed by the writer and the only one in 30 years' of observation of the night sky in this latitude in which the auroral curtain was seen south of the zenith occurred the night of March 22-23, 1920. The periods of rapid changes and more intense activity were for about 20 minutes each at 7:45 p. m., 9:45 p. m., and 12:30 a. m. During the remainder of the night there was a white, patchy auroral glow over the entire sky, with occasional streaks, that resembled thin cirro-stratus clouds illuminated by moonlight. The light cast on the terrain was equivalent to that given by the moon when nearing second quarter.

Vertical streamers from the northern horizon were not seen, and the center of activity, instead of being as usual on the northern horizon, seemed to be a little south of the zenith. Principal features of the display were: A brilliant northern curtain at 7:55; a corona and "flying eagle" at 8:08 p. m.; a dull northern arch at 9:50 p. m. which receded southward and became a brilliant curtain south of the zenith at 10:10 p. m.; a general white glow with patches of flickering light resembling heat lightning at 10:30 p. m., and a display similar to that of 8:08, which the writer did not see, at 12:30 a. m.

The northern curtain (seen at 7:55 p. m.) was clear-cut, crenelated, and the sky toward the north was black.

The black silhouette of the "flying eagle" (seen at 8:08 p. m.) was sharply defined, the body about 1° long and the spread of each wing about 1½°. The position of the bird was as though flying toward the west with the wings outstretched toward the north, but it was stationary and a little to the south of the zenith. Innumerable dancing rays of light radiated out from it, with delicate shades of green and pink.

The southern curtain (seen at 10:10 p. m.) was also clear out and bright and was preceded by dull white, quiescent northern arch that bordered on the north the general white of the sky and then gradually rolled back to the south past the zenith and became transformed into the southern curtain. When the southern curtain was present the sky overhead and in the north was black, free from auroral light of any kind. The stars shone.

A noticeable feature of the northern curtain was its apparent nearness. It seemed to be at the usual height of cirrus clouds.

There were no clouds in the sky during the night.—*J. R. Weeks.*

40. *Grand Haven, Mich.*—Soon after 8 p. m. * * * a band of light with comb-like edges extended east and west through the zenith. It underwent rapid change of form. About this time streamers and coronations began playing and shooting across the sky in all directions and from various points of origin. At about 8:30 p. m., southeast of Gemini a few degrees, there was a central area from which flame-like and fan-shaped flashes proceeded in all directions. * * * Faint separate flashes, resembling lightning, appeared in various parts of the sky interspersed among more distinct streamers. The entire display would at times almost cease throughout all portions of the heavens, and when it recommenced the luminosity would first be observed in

the north. Greenish-yellow was the most common color, but there also appeared reddish and bluish tints. The radiance much of the time was projected far to the south of the prime vertical, while in the southeast and south there persisted a whitish glow resembling the sky-reflections of a distant fire. The greatest brilliancy of the spectacle was from 8 p. m. to 9:30 p. m.—*H. Trullsen.*

41. *Ivoryton, Conn.*—Just before 8 o'clock * * * In the NE. and toward the N. there were shafts of light almost like searchlights that appeared to be coming out from behind clouds and shooting up into the sky, but I soon discovered that there were no clouds; the brightness made the sky close by look darker by contrast. All across the N. and NW. sky streamers of light shot up, meeting at the zenith, or rather a little to the SE. of it; in the NW. the light was more diffuse and pinkish, in the N. and NE. it changed constantly, now marching across the sky from N. to E., now appearing in horizontal streaks as the sun sometimes breaks through clouds just before it sets, now mounting in spirals of light, and oftenest of all looking like a curtain waving in the wind with light shining on its folds.

Sometimes all the light was gathered at the zenith like the folds of a tent, or as if one were looking at Mt. Fuji from above. The lights were greenish and yellowish white, with now and then fairly bright flashes of color, pink and green, gone almost before you could see them.

* * * The finest of the display after 9 was at the zenith. At first the light was like thin, filmy white clouds, like the Milky Way, only brighter. One curious thing I noticed, it did not dim the stars at all; they shone equally bright through the clouds of light or in the dark spaces of the sky between. These clouds of light shifted and changed every instant, flickering like firelight, only faster; often the light would seem to start near the northern horizon and mount to the zenith by a series of flashes, like jerky moving pictures; sometimes it mounted by quite regular corkscrew spirals, but it all seemed to focus at the zenith. More light came from the NE. and N., but the central focusing point moved south, so I had to turn and face that way after a while.

All the light would gather overhead and the rays would spread over nearly the whole heavens; gradually the filmy clouds grew brighter and more solid; an irregular curve would flash off and on several times changing its shape very little and only gradually, it would be in the center of a dark part of the sky, the rays radiating from the outer circle.

Sometimes just overhead the light came and went like the little waves on the margin of the sand when tide is nearly out; all the time there was constant shift and play all over the sky. These lights were colorless; gradually they grew more stationary and still whiter; a river of light appeared to flow up from the NE. and cross to the W. one broader, brighter band and several dimmer ones parallel with it; off to the north was a small spot of light like the Magellanic clouds, and as the broad band gradually moved south this small, luminous spot moved, too, without changing its shape, keeping always the same distance from the broad band.

Then suddenly in the E. and NE. it grew very bright, so that the whole landscape was lighted up, and then the light was all concentrated overhead and there was a most wonderful display of light and movement with bands and spirals and spots of prismatic colors appearing and disappearing in flashes. It was like looking into an inverted cone made of rays of light. The colors were wonderful, pink predominating; sometimes a rosy glow was over large parts of it. This lasted perhaps two minutes, but not at the brightest that long; it gradually changed to white and shifting lights with one big, snaky spiral at the zenith and rays shooting up from the horizon. Later the flashes were white and like distant heat lightning in summer. There was a good deal of light in the south late in the evening; earlier there had been very little.

All the time the sky was clear and the stars very bright; a slender crescent moon was shining low in the west when we first went out, I kept thinking, clothed with light as with a garment. The light seemed to have body, as if you could grasp it as you could a curtain. After this we saw the Northern Lights several nights but only as streaks of light in the north, nothing to be compared to the display on the 22d.—*Ethel C. Comstock.*

42. *Plainfield, N. J.*—Phase "A" from 8:30, when I first noticed the aurora, to 8:45 was characterized by a moderately wide glow to the north with some streamers, though not brilliant, streamers with greater brilliancy, however, coming up from the east well toward the zenith. * * *

Phase "B," 8:45 to 9:45, showed comparatively little glow and scarcely any streamers from the north, but quite strong ones occurring a little north of west and with maximum strength almost due east, but extending both north and south of east. Streamers from the east seemed to preponderate slightly in brilliancy merging with those from the west in a fairly broad band of misty white light across the zenith.

Phase "C," 9:50 to 9:52, when I noticed increasing brilliancy and got to the roof, streamers were spreading from east and west rapidly toward the north and south to form as they did later a complete circle. The horizon, and up for about 30° or 40° was free from any light, comparatively black.

During the next three minutes, phase "D," 9:52 to 9:55 (please note that the times are merely guesswork as I did not take time to look at

my watch while observing the aurora), shows increasing number of streamers and brilliant light, still white, equally distributed in all parts of the circle, extending from a distinct luminous circular border about 40° above the horizon, below which everything was black, to the zenith where at times there was a "hole" of complete blackness and at other times what looked like light, fleecy clouds swirling about. Of course, they were not clouds but had that effect, looking at the streamers endwise.

In phase "E," at just about 10 o'clock, I noticed a forked-shape light starting almost in the west from low down near the horizon, rapidly extending toward the zenith and growing tremendously in brilliancy until it attained the order of brilliancy of the moon on a clear night, and an equally brilliant light starting from the east and as rapidly as the one in the west, approaching the zenith, also growing more brilliant. This certainly started something up above. All of the streamers appeared to take on additional activities and iridescent coloring, especially all around the zenith, and extending practically down to the edges of the display, with a reddish color predominating toward the west. The east and west flares disappeared only to be followed by four or five other pairs of not quite so great brilliancy, starting simultaneously and reaching the zenith, disappearing together, each pair to be followed quickly by another. These flares, always in pairs, one east and the other west, so far as I observed, originated not more than 15° north of the east-and-west line, but the brilliancy of the dome or funnel above me appeared to be equal in all directions. Immediately at the zenith there was either a black hole of some 10° or else a swirl of fleecy "clouds."

This proceeding I suppose did not last more than 2 or 3 minutes, during all of which time there was no vibration apparent, except longitudinally of the streamers, i. e., radially from the circumference to the zenith, but at about 10:05, suddenly there were great concentric waves passing with great rapidity from the outer edge toward the zenith. I should say there must have been about 10 distinct waves visible at any particular instant and it probably did not take over a fifth of a second for any particular wave to pass from the bases of the streamers to the zenith. All of this is merely guesswork.

This manifestation of concentric waves appeared to be the beginning of the break-up. After they started there were no more flares of light such as had been occurring up to that time.

The iridescence disappeared gradually, except for a red glow which remained for some time in the west. The entire circular effect had practically disappeared by 10:15 and thereafter the aurora reverted to a condition similar to that from 8:45 to 9:45, and continued in that condition with more or less variation in brilliancy until 11 o'clock, at which time I retired. At 1 o'clock I was awake. It was then of considerable less brilliancy, the condition being somewhat like that at 8:45.—*Henry B. Newhall.*

43. *Cleveland, Ohio.*—An aurora of unusual brilliancy at this station was first observed at 8:30 p. m., with faint streamers and sheets of light in the east and west, and a pale light between. By 10 p. m., a spot about 15° south of the zenith began to radiate bands and sheets of light. The display reached its maximum brilliancy at 11:30 p. m. At this time the arch in the north became more prominent with rays of light shooting upward and with traces of the curtain effect below, but this was nothing compared with the display at the zenith, where ever-changing streams of light took on the greatest brilliancy. Sometimes these sheets and bars of light showed spectrum colors at the horizon. The display lasted to midnight and it was continuing at midnight.

44. *Detroit, Mich.*—An aurora which was first observed at 7 p. m. of the 22d continued until after midnight. When first observed the streamers of white were over the northeast and extending to the northwest; the streamers were not active at any time, but between 8 p. m. and 8:45 p. m. extended at times to the zenith. The white auroral nebulous cloud was observed during this period to the southeast and then south and clear around to the northwest; this cloud extended, however, from about 40° to zenith. There were no colors visible in the streamers except a very light crimson at times in the northwest. The dark auroral cloud was visible in the northeast. The display continued off and on until midnight. After midnight it was reported to be entirely confined to the south and was high at all times; the display lasted till about 1 a. m. on the 23d.

45. *Detroit, Mich.*—About 9:50 (eastern standard time) an arch approximately 9° wide appeared across the heavens from the northwest about 10° south of Jupiter, 12° south of Regulus, through Spica to the horizon a little east of where Mars had just risen. It seemed to be fairly uniform in width, but very irregular. This changed to a cone of light that stretched from the horizon on all sides to the apex, exactly in the radiant of the Leonids. At this phase it was so brilliant as to blot out all stars below the first magnitude. The colors were pale, except for a pronounced ruddy color south of Jupiter and Saturn. * * * The light was brightest in the south and southeast, but covered the whole sky. It occurred in spasmodic outbursts of brilliancy until daylight.—*W. B. Kennedy.*¹⁶

¹⁶ Reprinted from *Popular Astronomy*, May, 1920, p. 308.

46. *Sandusky, Ohio, March 22.*—No clouds. Aurora first observed at 7:45 p. m. The northern sky had a luminous appearance with an arch extending from northwest to northeast from which bright streamers, of a greenish hue, extended toward the zenith. The greatest elevation of the arch was about 20° above the horizon. One streamer of a reddish tint was observed in the northwest. The greatest activity of this early display occurred between 8 p. m. and 8:15 p. m.; after a time the display became less bright, but the light of the aurora overspread the whole sky, except the extreme southwest portion, and gave to the sky the appearance of being overcast with a thin cirrus cloud-sheet. No particular changes were noted thereafter until about 9:45 p. m., at which time parallel bands of light extended across the sky from about 20° above the eastern horizon and from the Pole Star to the zenith. These bands rapidly converged, and at 9:55 p. m. two bright patches appeared at (about) altitude 50° and azimuth 125° [about over Ypsilanti; see 47], and 305°, respectively. From these bright patches, which remained for about 10 minutes, greenish-white streamers radiated rapidly in all directions. From 10:05 to 10:15 p. m. the brightness of the aurora rapidly decreased, but at about 10:30 p. m. renewed activity was observed, the white cirrus-like sheet again overspreading nearly the whole sky with waves, not streamers, of white light extending from about 20° above the northern horizon to and beyond the zenith. This display was maintained for about 15 minutes, during which time the surface of the earth was lighted by the aurora nearly equal to that by the moon at quadrature. After 10:35 p. m. the display again decreased in brightness; the arch with streamers was again observed in the north, but the light was quite faint, and by 11:15 p. m. the display was practically over.

47. *Ypsilanti, Mich.*—These notes were written on the same evening that the observations were made:

"At 8 it was very brilliant in the north. The light at that time seemed to be in patches, changing to vivid vertical rays, that changed rapidly and shot up and down. This light would again change to a very bright narrow belt running from east to west but not perfectly regular. At times there were two such bright belts, not parallel, but more or less inclosing regular space. The entire aurora moved southward until before 10 it had passed through the zenith. At one time there was almost directly at the zenith a dark space, from which, as from a center, rays of light radiated. At another time a narrow band of bright light extended through the zenith from the eastern to the western horizon. Shortly after 10, almost the entire sky was filled with light. Flashes of light went in short, successive, pulsing waves from the eastern horizon to the zenith. At this time the sky was bright all around—north, south, east, and west. It was almost as bright as the light furnished by a half moon."

In addition to the foregoing notes, kindly permit me to add that the features of this aurora that distinguished it from others that I have observed, were the extraordinary brightness, the passing from the north through the zenith, until the auroral center seemed to be about 45° above the southern horizon, the pulsing waves that reached from the east toward the zenith, the unusual activity, and quickness with which the changes were made.—*Nathan A. Harvey.*

48. *Ann Arbor, Mich.*¹⁷—[At about 7:05 90th mer. time] * * * I noticed a few streaks in the western sky, but thought they were wisps of cloud. However, I soon became aware of their auroral nature. Then an auroral haze appeared, stretching along the equinoctial, from the horizon through Orion. Brighter streamers now began to shoot up from the northern, eastern, and western horizon and the flickering became noticeable. Until about 7:30, no color was seen, but the streamers then began to take on a light green tint which became more and more pronounced. The green was especially noticeable in the northeast where the aurora took the form of a beautiful curtain hanging down to within about 20° of the horizon at the north, arching upward to Mizar and downward to Arcturus.

Several times it appeared as if the display were coming to an end, but each time it began again, more vigorously than before. By 8:30 it covered practically the entire sky, the streamers flashing up from the entire circumference of the horizon and meeting, in general, at a point about 20° south of the zenith. (The dip of the needle at Ann Arbor is 73°; or 17° from the zenith). I will call this point the "radiant" for convenience. The haze in Orion had disappeared entirely by this time.

At about 9 o'clock, the streamers began to flash vigorously and they grew brighter momentarily. Suddenly there was a veritable explosion. Like flashes of lightning, the east and west streamers shot up, glowing brilliant green * * *. A great double arch formed in the space of a minute or so. It stretched from west to east through the radiant. It was brilliant green with pale red borders and flashed like flame. In about five minutes it was gone, although fragments of it seemed to linger for some time. The entire sky within 30° or so of the radiant turned violet and the whole horizon glowed with a still brighter green than before.

Although the display was still quite brilliant it had now passed the climax. By 9:30 the region of the radiant had become dark; only an

occasional flicker appeared there. The color faded also, and by 10:30 the greater part of the action was in the east and west, with only a slight tinge of green. At about 1 a. m. the activity had increased somewhat and the color had become more marked, but I did not observe it any longer.

During the display I noticed the following curious facts: Before midnight, in the northwest quarter of the sky, streamers forming in the north drifted slowly toward the west; in the northeast quarter, try as I would, I could not determine any definite drift. After midnight, in the northeast quarter, there was a drift from north to east, but I could detect no drift in either direction in the northwest quarter. Does this indicate solar influence? * * *—*Dean B. McLaughlin.*

49. *Ann Arbor, Mich.*¹⁸ * * * Though active streamers and other features often centered in and toward the north and were delimited below by a marked black arch, at times perhaps the northern third or more of the sky was nearly devoid of visible aurora light while most of the rest of the heavens was illuminated. A well-defined southern black arch was seen at intervals, having a meridian altitude of perhaps 20° or 30°. When last observed (about 2 a. m.), there was no auroral light in the northern half of the sky. The southern black arch was well defined and above it was first a green arch and still higher a stronger one distinctly yellow in color.

About 10 p. m. an auroral curtain answering well to descriptions of such displays as witnessed in polar regions was observed in the southeast for about 10 minutes. This curtain was centered at an altitude of about 60° and extended some 30° right and left, with folds in an apparently vertical direction about 10° long. Shortly before this curtain appeared the light in the southeast was strong enough to cast a noticeable shadow.—*R. H. Curtiss.*

50. *Wilmington, Del.*—I first observed the aurora at about 7:20 p. m., when a few faint light green spots flickered around almost due north and 20° above the horizon. Within the next half hour these spots spread considerable toward the northeast and approached the zenith. Several times there were very well-defined examples of the spiral hanging curtain, so often illustrated in works of Arctic explorers. Very few spots of light pink occurred. The electrical impulses traveled upward from the horizon toward the zenith and at times markedly from the east toward the west (as if the earth were revolving through a field of such electricity). An hour or more later there was a very bright green spot to the west and about 30° downward from the zenith. This grew and spread with many fluctuations of brilliancy and in time the sky was almost entirely illuminated in light green, from the northern horizon past the zenith to 40°, approximately to the south of it, where the illumination terminated abruptly in a east-west line. The zenith was marked by a darker spot toward which long radiating lines extended from every direction, the electrical impulses traveling in pulsations along them from the horizon to the zenith. The light seemed to illuminate sheets and wisplike clouds of gas, the whole having the appearance of a luminous cloud. The appearance of convergence above must of course be due to perspective. When I retired at about midnight the display was still very bright.—*Alfred C. Hawkins.*

51. *Devon, Pa.*¹⁹ * * * When first observed (midnight) the base was (eye measure) about 20° above horizon all round, south, north, east, west, rising to about 30° by 12:45 a. m. From ENE., round by north to NW. by W. (eye measure, no instruments) there was the characteristic arched base, but broken in places by irregularities. The rays above this base gave the impression of thicker mass and steadier glow—probably because the field covered was more extensive (thicker), but was not as bright as from ENE. to ESE., often WNW. to WSW., which I will call East and West, the rest North and South portions. The South portion was "thinnest" and had no well-defined base, and stars could be seen below and at times through it, but it was very exceptionally bright for any aurora in this latitude. It was rather more active than the North, but not as active as the West was most of the time. The East was far the most active, the West occasionally rivaling it. East was much denser than South, and generally [more so] than West, and occasionally as dense as North. Rays from all quarters met in roughly a circle about 5° in diameter with north edge about 10° south of zenith. * * * Sometimes rays from one side would reach it, sometimes from several or all quarters at once. It was the target for all rays and all long enough reached it.

The rays from the north moved less rapidly—about average for auroral rays I have seen. Those from south much more rapidly as a rule. The West were still more rapid, occasionally rivaling East (speeds of all probably the same, with general motion from the east—apparent differences due to relative distances). The East rays moved occasionally deliberately (as all did) but generally with exceptional rapidity, and often I was barely conscious that there was motion, it was so rapid—almost an instantaneous outbreak from base to upper end of circle. There at times great mass glows in east and occasionally west that were only suggestive of rays by their upper and lower edges being broken in a ray-like manner from the West looking like cloud. These generally had no motion and came and went instantly or slowly. Occasionally they had an upward motion, sometimes very rapid.

¹⁷ Reprinted from *Popular Astronomy*, May, 1920, pp. 308-309.

¹⁸ Reprinted from *Popular Astronomy*, May, 1920, p. 307.

Color, whitish to faint yellowish—no blue, green, or red. East part the most active. Rays of light masses all round all the time, but except about 30° above or below the northern arch stars could be seen in every quarter at times and unusually near the horizon, indicating a clear atmosphere. The brightest light was in the East—next, at times, West, then North—least South.—*F. R. Welsh.*

52. *Pittsburgh, Pa.*—The auroral display of March 22 and 23 was by all odds the most magnificent ever seen in the vicinity of Pittsburgh. It was possibly equaled in brightness by one which occurred on September 11, 1908, though the display on that date was much less imposing because the sky was illuminated by a full moon.

It was undoubtedly in progress during the afternoon, for as soon as darkness settled down the aurora was brilliant over all the sky except the extreme southern portion. At that time it appeared like patches of hazy cloud illuminated by yellowish light.

It is very difficult to describe a phenomenon so varied in its manifestations, and so dazzling in its beauty. From pictures I have seen of Arctic auroras, this bore considerable resemblance to them. There were the same sinuous lines of brightness extending in a more or less horizontal direction near the northern horizon. From these as a base streamers extended up to the zenith, constantly changing in brightness from one point to another, thus giving the appearance of the waving auroral curtains so often mentioned in connection with the Arctic auroras. The general shift of the streamers was toward the west.

The convergent point of the streamers was in the meridian, and about 15° south of the zenith. Its position remained practically unchanged throughout the night. At the most brilliant period of the display it resembled the tip of a great umbrella of fire with luminous ribs extending in every direction. The colors were not very strong, mostly greenish yellow, though pink appeared at various times and in various parts of the sky.

By 9:30 the display seemed to be nearly over, but about 10 o'clock it recommenced with more vigor than before, and then came the most wonderful part of the whole display.

From the west appeared what seemed like a great brilliant comet with a very bright, strongly curved tail which gradually spread toward the northeast until it made a great arch spanning the whole northern sky. Under this arch it was darker than elsewhere. From the lower edge seemed to depend innumerable arrow-like points. Its color was white. Then began great pulses of light running from all the northern half of the horizon, and even from the south of the east and west points, to the radiant point. These succeeded each other with startling rapidity, so that almost the whole sky seemed to be a quiver with a weird light.

The whole effect was indescribably grand, and gave the beholder a feeling of awe as all this tremendous manifestation of electric forces proceeded without a trace of sound. This portion of the display lasted less than an hour, but the aurora persisted till daylight. At 3:30 a. m. it would have been considered an unusually fine aurora had we not had the display of the earlier part of the night. At this time it consisted of the usual bright auroral arch from which proceeded numerous streamers. It was still faintly active at dawn.—*Frank C. Jordan. (Allegheny Observatory.)*

53. *Delphos, Ohio.*¹⁹—Probably the most spectacular aurora of recent years occurred on the evening of March 22. Though perhaps lacking some of the intense color of the display of March 7, 1918, it more than equaled it in the variety of interesting forms which it assumed.

It was first seen at 6:50 p. m., though probably noticeable before this. Even as early as 7 p. m. many streamers from the north and northeast reached the zenith and the colors of red and green were quite prominent.

The maximum of the display occurred about 9:10 p. m., when it assumed the curtain form in the east. Replete with color and shaken with great rapidity, it was bright enough to cast a dark and well-defined shadow. The dark upright bands in the curtain moved always from the east to west. * * *

The display lasted throughout the night and was still present to some extent the following evening. * * *—*L. C. Peltier.*

54. *Indianapolis, Ind.*—[At 7:30 p. m. there was] * * * a greenish white glow in the north which extended almost to the zenith. There were slight traces of bands from time to time and later a diffuse arch stretched from the star Gamma Andromedae in the west up toward the North Star and down to Arcturus in the east.

A few minutes before 9 p. m. a fine arch appeared low in the north with upright rays which brightened and faded as if they were rotating on an axis. The arch climbed higher in the sky and beams shot up from it and disappeared. Patches of red in the east and west appeared at various times. However, red areas of light were not as conspicuous as on former occasions. Soon the east was ablaze with greens and yellows which shifted to the north. Weird lights appeared like a clearing at twilight, after a storm. It was bright enough to read a watch dial and objects held close to the ground cast a distant shadow. About 9 p. m., radical pencils of whitish light shot from the northern horizon towards the zenith and a few degrees beyond, where they met

between Jupiter (at present in the constellation Cancer close to the naked eye star cluster known as Praesepe), and the Sickle of Leo, silently "exploded" with much twisting and infolding, and dropped a canopy of yellowish white light, streaked with red and violet, over practically the entire sky. The whirling clouds of the "explosion" looked like cumulus lit up by lightning. A few minutes later, they were much fainter and more like wisps of cirrus set radically around the region of Leo and Jupiter. They remained for almost an hour in that part of the sky. The formation of the canopy occupied only a few seconds and the luminous region extended as far south as Sirius. Immediately after the "explosion," flickers and waves of light shot from the north to the focus in Leo within the fraction of a second, chasing each other with incredible speed. They seemed to skip the dark tracks of sky and light up auroral clouds beyond. Once or twice they appeared to generate new rays in dark spaces.

By 10:20 p. m., the region of Leo was dark and the light in the north appeared to be gathering strength for another display which consisted of a smaller arch with short upright rays, flickers and waves of light.

From 11:45 p. m., to 12:35 a. m., March 23 a band stretched across the sky from Castor and Pollux in the west toward Vega in the east and about 5° to 10° above the North Star. Soon it made a zig-zag like the letter Z (similar to the aurora of March 7, 1918) and drifted north to a position below the North Star. * * * [Flashes in quick succession from north to south at times] caused patches of light to shine in other parts of the sky.

1 a. m. lights again appeared in the north and broad radical streaks extended from the northern horizon towards the original focus, formerly in Leo, now occupied by Arcturus. * * *

1:30 a. m. a faint glow was still visible in the north and there was drifting haze below the bowl of the Big Dipper.

1:45 a. m. there was some haze near the North Star and faint broad streaks overhead.

1:50 a. m. broad, cloud-like patches appeared south and west of Arcturus.

2:30 a. m. a faint vertical bar of light was visible near Deneb in the Northern Cross.—*Russell Sullivan.*

55. *Abbe Meteorological Observatory, Cincinnati, Ohio (90th mer. time).*—The aurora borealis was first observed at 7:50 p. m. as an arch of light along the northern horizon. When first seen it was a diffused glare of white light without streamers, and extending about 30° above the horizon. During the following hour there appeared to be but little change, either in the position or size of the aurora, except that short streamers were occasionally visible.

At 8:55 p. m. streamers began to grow rapidly toward the zenith, first in the northwest and later in the north and northeast. Between 9 p. m. and 9:10 p. m. the streamers formed with great rapidity and became very bright but showed little color. The light extended a considerable distance beyond the zenith and for a few minutes the southern edge of the aurora formed an arc across the southern horizon about 45° high in the center, the southern cloudless sky appearing unusually dark. All of the streamers met at a point about 7° south of the zenith, the streamers from the north and northwest being very long, bright and well-defined, and those from the south comparatively short, poorly defined and of diffused light. The only pronounced color observed was a pinkish red glow in the northeast, which extended slowly up to the zenith and gradually died out.

After 9:10 p. m. the streamers disappeared even more rapidly than they had formed and there remained only patches of white glow in the upper portion of the sky extending about 30° in all directions from the zenith. Then followed a most remarkable display of flashing light through this field of patches. In contrast with the streamers these flashes moved like waves, and very rapidly, being in appearance somewhat like distant lightning and in movement somewhat like a mist or fine rain driven in a gale. By 9:30 p. m. the aurora had practically disappeared, but it reappeared again in the north before 10 o'clock and continued at midnight as a dim glare, showing some streamers.—*W. C. Devereaux.*

56. *Nashville, Tenn., March 22.*—About 9:05 p. m. * * * the northern sky showed yellowish green from near the horizon to a height of about 30°. Above that and almost to the zenith a red glow was observed. For a few minutes distinct bands or streamers of varying width extended upward, fan-shaped. These were less numerous and very faint by 9:15 p. m. A faint glow, maintaining the yellow color below and red above, continued for some time after this.

57. *Chattanooga, March 22.*—A beautiful aurora borealis was observed in the north from about 9 p. m. to 9:42 p. m. Streamers began shooting upward until five were observed, two pink and three yellow, reaching about 10° above the horizon with a quivering motion.

58. *Warren, Ark.*—From 9 to 9:30 p. m. [the aurora] had the appearance of rays of light similar to rays often seen when the sun is behind a small cloud, except they seemed perfectly straight and parallel and had no common center. The rays were very distinct and moved rapidly up. [A central shaft] * * * made its appearance at the horizon and in less than a minute it reached the Pole Star.—*J. L. Clegg.*

59. *Fort Worth, Tex., March 22.*—Aurora prevailed from about 8 p. m. to about 10 p. m., the sky was cloudy but light-way pulsations of a

¹⁹ Reprinted from *Popular Astronomy*, May, 1920, p. 312.

pinkish and green shading and tintings flowed earthward [?] at intervals varying from one to three minutes, yet a constant glow was in evidence.

60. *Houston, Tex.*—On the evening of the 22d all telegraph wires were badly affected and could not be operated or operated with difficulty only. A flickering white light in sheet-form was observed in the northern sky at 10:30 p. m. which is thought to have been an aurora borealis. No arch or streamers were observed.

61. *Bismarck.*—An unusual auroral display was observed on the 22d from 9 p. m. until about midnight. Streamers were first observed in the north. These increased in number and extent until, at the time of greatest brilliance at 10:30 p. m., they issued from all points of the horizon. The longer streamers met at the zenith. There was a marked fluctuation in the brilliancy of the light.

62. *Rapid City, S. Dak., March 22.*—A most extensive and gorgeous display of the aurora was first observed about 7:30 p. m., local time, * * * as a whitish haze in the northern sky, gradually becoming denser and taking on a reddish hue. At 7:45 p. m. streamers or shafts of light began shooting upward resembling a strong searchlight when seen from a distance. At intervals the streamers were colored red and greenish. By 8 p. m. the aurora had spread from 90° to 270° azimuth, and the streamers appeared to converge at a point near the zenith, gradually extending until they reached the horizon in the south. About 8:15 p. m. the whole sky appeared to be filled with streamers of white light extending from the horizon from all directions, and meeting at the zenith, but evidently those in the south were overshot from the north that reached entirely to the horizon in the south. No arch was visible at any time. The display disappeared about 9 p. m. Some persons report that the display was repeated about 11 p. m. to midnight. * * *.—*H. N. Johnson.*

63. *Cheyenne, March 22-23.*—An aurora was observed at 11:30 p. m., March 22; it had evidently been on for some time as it was then in full glory. The colors varied from streamers of pink-red to streamers of yellowish-green, and fields of yellowish-green. Some of the streamers reached to zenith. A peculiar phenomenon was waves of light that seemed to originate at about altitude 20° and flicker upward to about an altitude of 80°. The display extended from approximate azimuth 140° to 230°. At 12:25 a. m. of the 23d it was faint but distinct.—*G. W. Pitman.*

64. *Albuquerque, N. Mex.*—[The aurora was] * * * a roseate glow, shading to a green light, with darting lights shooting far up into the sky * * * [lasting] from about 8 o'clock to nearly midnight.—*Albuquerque Morning Journal.*

65. *Kayenta, Navajo County, [northeastern] Ariz.*—* * * A low light bank appeared in the north at about 10 o'clock [12, midnight, 75th meridian time]. This gradually advanced toward the zenith, as bright streamers shot southward from it. From white settlers and Indians the writer could learn of no previous auroral display in this immediate section.—*Albert B. Reagan (superintendent Marsh Pass Indian School).*

66. *El Paso, Tex.*—An electrical display, probably aurora borealis, was seen by several parties shortly before and after midnight of the 22d. As described, there was a diffused light just above the horizon due north of the station, with streamers or jets of flame reaching at times several degrees above the horizon. One person said it looked as if there were a town or several oil wells on fire.

67. *Calgary, Alberta.*—* * * At 11 * * * I noticed quite a brilliant display of vertical streamers in the west. They extended, when first observed, from about 70° west of north around through to south to about 50° east of south, and could be traced to an altitude of perhaps 60°. After a few minutes they began to spread until they extended around the whole horizon making a very brilliant display, much the most brilliant I have ever seen. Besides the greenish light usually seen in such a display nearly all the colors of the rainbow were observed. A lot of blue or purple light was observed near the north and extending to the east. A little south of east an intense crimson was observed extending about 20° in latitude and lasting for some time. It was directly over the center of the city and looked very much like the reflection from a fire. This intense red seemed to extend only to the top of a low-lying cloud. Toward the end of the display it gradually faded and died out while there were a considerable number of vertical streamers still visible.

After the vertical streamers had spread till they extended around the whole horizon they became still brighter and spread upward until they formed a corona near the zenith. They finally met in the center but the light was more or less fused and one could not determine any sharply defined point of intersection. Assuming that Tenth Street NW. runs north and south, it was approximately 10° south and 5° west of the zenith. The diffused light formed a sort of brilliant ever-changing cloud about the zenith which kept breaking along a wavy line in a general north and south line, separating into two halves with a dark cleft between them and subsequently reuniting. Many of the lights which give the effect of a waving sheet of changing colored gauze suspended from the sky were also visible. * * * They were mostly to the south of me.

* * * The light which caused the vertical streamers seemed to be extending in waves vertically upward from the horizon, the waves following each other in very rapid succession, four or five being visible simultaneously, one above the other. The waves were not separated

by dark spaces; they were merely points of intensified light. These waves extended across many streamers or were synchronous on all streamers in one's vision. This effect of ascending waves of light was most noticeable when looking toward the southwest, which was about the center of the display all through, and was not noticed until toward the end of the display but while the light was extremely bright. The light was sufficient to light the earth considerably, but I believe it would not have been sufficient to enable one to read.

By 12 o'clock the display had died down until it was not worthy of special notice. * * *.—*Owen Bryant.*

68. *Brewster, Wash.*—[The aurora] reached from due east to due northwest; also to zenith. Western edge colored red-orange-green, very bright and lasted until about 3 a. m.—*Wm. Saul.*

69. *Spokane, March 21, 22, 23.*—* * * [The] most brilliant display at Spokane occurred at 10 p. m. (120th meridian), March 22, in the form of intensely luminous beams radiating in all directions from a point in the zenith; the first indications some observers, at this place, had of this display were noted in the sky south of Spokane's zenith. This aurora and all indications of it had disappeared from Spokane by the morning of March 23. * * *.—*C. Stewart.*

70. *Seattle, March 22.*—The aurora borealis was first observed as early as 8 p. m. It became a brilliant display by 10 p. m. and continued till past midnight but becoming dimmer after 11 p. m. and apparently shifting to westward.

When brightest, the luminous arch spanned more than the northern half of the sky. Light rays converged to a focus somewhat south of the zenith and then diverged. At times patches of light flashed about 45° south of the zenith. At about 10:15 p. m. both in the northwest and the northeast the sky was rose-colored. After this the pulsation of streamers was more pronounced. The general color was white light to a very pale yellow with a suggestion of green. Telegraph companies and the cable office reported serious interference in transmission of messages owing to the earth's disturbed condition. This was true to a less extent on the night of the 21st and the night of the 23d.

71. *Yakima, Wash. (120th mer. time).*—The aurora [appeared] * * * as early as 7:30 p. m. on the night of March 22. About 9:45 p. m. a wide arc stretched across the zenith from a little south of due east to a little north of due west. At 10 p. m. there was a broad, curving arc in the north, with rays extending up from it, which a few minutes later extended beyond the zenith, converging to a well-defined point. A little later, most of the rays faded out for the greater portion of their length, leaving a particularly brilliant portion near the zenith. All this was colorless, except for a reddish tinge in the east, and some reddish streaks in the northwest. At 10:10 p. m. the rays reappeared for their whole length, and became much more pronounced, successive waves of light passing from the arc near the northern horizon up to the zenith. The red streaks in the east and west became more noticeable. By 10:25 p. m. the bands were farther from the northern horizon, and the rays much dimmer and more diffuse, although waves of light still occurred. The area between the arc and the horizon appeared darker than any other portion of the sky, as did a part of the sky south of the eastern part of the light area. In both cases stars were observed shining in these areas.—*E. J. Newcomer.*

72. *Walla Walla, Wash., March 22.*—I first noticed the aurora about 9:15 p. m. as a bright band of light about a quarter of the distance from the horizon to the zenith, stretching from northwest to northeast. Closer observation showed a very bright patch of sea-green light rather low down on the horizon and a little later a dim rose-colored patch to the northwest. After a time long streamers began to form and extended from the patch of green in the north well up toward the zenith; these were almost steady at first but began to waver and gradually grew dim, finally ceasing altogether. A few minutes later the whole northern sky was lighted up with intermittent flashes of light of greenish-white cast, so bright as in some cases to blot out the stars. These flashes shot up from the horizon with great speed and looked like green vapor being blown by the wind, the green at times changing to copper color.

* * * There was still a bright greenish light to the north at 11 o'clock when last observed.—*R. H. Desmond.*

• 73. *Boise, Idaho.*—In the March number of the Bulletin I note a request for descriptions of the aurora of March 22. In response thereto, I submit the following:

* * * At about 8 o'clock * * * [there was] a faint bluish-green glow down on the northern horizon.

* * * The glow gradually increased in brightness and also in extent. In about an hour, it had extended to about 80° of the horizon and about a height of 35° above the horizon. At about this time the streamers became visible, some of them eventually reaching as high as 45°. By 10 o'clock the spectacle had reached its maximum intensity and beauty. At about 11:30 I observed a reddish tinge to some of the streamers, although it was very faint—the predominating color throughout being the bluish-green. Some of the streamers appeared to stream out from the horizon, others seemed to appear almost simultaneously their whole length. At about this hour (11:30), I observed a sort of radiation from the base of the streamers upward. This radiation appeared as a dim, but regular, arc of comparatively bright light which arc was parallel to the arc of the aurora. This arc passed rapidly from the base to the limits of the aurora, occupying about one second to

cover the distance. There was a rapid succession of these "radiations" which varied greatly as to brightness, and gave the effect of enormous tongues of flame leaping upward. At no time during my observation was this "radiation" very bright, but its peculiar nature made it quite conspicuous.

There was considerable variation in the place of greatest brightness along the horizon. At one time, I observed that that the west end of the display was much more brilliant than the rest; at other times, the brightest part was the east end. For the most part, however, the center of the illuminated area was the brightest. I continued my observations until well past 12 o'clock, and at that time the glow was as brilliant as ever.—*Charles W. Fanebonger.*

74. *Fresno, Calif.*—An aurora was observed here from 10:45 p. m. to 11:15 p. m. of March 22 by Roy E. Miller, editor of *Associated Growers' Magazine*. Note of his observation was made in our records at the time and I find it to be the first and only occurrence of this phenomenon here that has been entered in our records.

He reported the sky as partly overcast at the time with a bank of dense dark cloud [the characteristic dark segment of clear sky (?)] with clear-cut margin lying along the northern horizon, which seemed to heighten the contrast with the reddish, white, and violet streamers of the aurora above. Our latitude is $36^{\circ} 43'$.—*C. E. Bonnett* (U. S. Weather Bureau).

We wish to extend our grateful acknowledgments to all those who sent their descriptions to us, and to the numerous U. S. Weather Bureau observers who took the pains to enter accounts of the aurora in their meteorological records. In addition to those whose names appear at the end of the published descriptions, notes were received from the following: Robert H. Allen (West Roxbury, Mass.), F. Z. Hartzell (Fredonia, N. Y.), Charles W. Leng (Staten Island, N. Y.), L. B. Bonnett (Elizabeth, N. J.), J. W. Harshberger (Philadelphia, Pa.), T. P. Irving (Notre Dame, Ind.), W. S. Gorton (East Orange, N. J.), H. G. MacMillan (Greeley, Colo.), E. B. Scott (Dahlgren, Va.), S. S. Visser (Bloomington, Ind.), Charles C. Hopkins (Rochester, N. Y.), A. T. Jones (Northampton, Mass.), George D. Rogers (Gloucester, Mass.). Published accounts not excerpted or reprinted here are to be found in *Popular Astronomy*, April and May, 1920, vol. 28, pp. 248, (North Scituate, R. I.), 310-311 (Chestertown, Md., Wellesley, Mass., Brooklyn, N. Y.).

TELEGRAPH AND RADIO EFFECTS.

It is interesting to note that there were numerous references to telegraphic troubles, especially during the periods of maximum in the magnetic storm. Thus, trouble was felt between Switzerland and France in the afternoon of March 22 and at the same time (early morning and till about 3 p. m., eastern standard time) in the United States and Canada, which led some people to be on the lookout for the aurora. The Atlantic cable service was adversely affected.

Radio communication, strange to say, is usually but little affected during auroras. The following note from Gloucester, Mass., is of interest in this connection:

The 10 o'clock radio time signals from Arlington [Va.] and a message immediately afterwards were listened to from a small antenna. No unusual static discharges were noticed, but the strength of the received signals varied enormously, from almost nothing to seemingly more than usual loudness. The periodicity was not regular, but slow enough to permit futile attempts at better adjustment during the minima, and the changes in strength were not abrupt.—*H. G. Dorsey.*

This was at the time of greatest intensity of the whole display, and there were at least three brilliant auroral curtains between Arlington and Gloucester.

BRIGHTNESS OF THE LIGHT.

The brightness of the aurora was the subject of special comment by many observers. The amount of light was estimated to be "as bright as twilight 10 minutes after

sunset on a clear day" (at Charlotte, N. C.), or equalling the brightness of the northwestern sky half an hour after sunset, or to cast a light equal to that of the moon in first quarter, or even full. Some mention how the brilliance of certain portions of the display would cast well-marked shadows and also how it was possible to read a watch.

The light at times may have been sufficient for reading. Fortunately, Prof. Joel Stebbins made some actual measurements of the intensity of the light, at Urbana, Ill.:

The auroral light interfered with our photometric observations at the telescope that evening, because of the variable bright background for any star. A few rough measures gave the result that a patch of auroral streamer equal in apparent area to the full moon gave about as much light as a second magnitude star. This refers to the blue light which most affects the photo-electric cell, which is not very different from the photographic plate in color sensitivity.²⁰

Some photographs were obtained, at various places, though the movement of the streamers makes it difficult to get anything sharp without special plates.²¹

THE END OF THE DISPLAY.

The best part of the auroral display ended with the maximum phase of the magnetic storm at 2 a. m. eastern standard time (7^h G. M. T.), but there was an unusual aurora during the following two hours, until the magnetic storm practically ended at $8^h 50^m$. The aurora was last seen at dawn at several places in the eastern United States; and Mr. William Saul at Brewster, Wash., says that it "lasted till about 3 a. m." (11^h G. M. T.). It seems probable that the aurora continued throughout the 23d, for it was visible again at dark that night.

The southernmost reports in different sections were Washington, D. C., Fort Worth, Tex., and Seattle, Wash. On the following night, March 24-25, people at northern stations observed a normal faint aurora, while a few in middle latitudes saw an unusual spot-light display, which would last for a few minutes, then fade away in a few seconds, only to reappear as suddenly. The behavior of these spots was not unlike that of the luminous clouds of two nights before, but the absence of streamers made the display look peculiar. A discussion of some angular observations made on these spots from widely separated places is published below, on p. 392. There are scattering reports of a faint aurora on the night of March 25.

AURORAS ASSOCIATED WITH PREVIOUS AND SUBSEQUENT PRESENTATIONS OF THE DISTURBED AREA ON THE SUN.

The great sunspot group responsible for this four-day aurora * * * was a revival of a similarly extended group of spots of large area observed from January 21 to February 3. At the next rotation, February 17-27, this group appeared as an insignificant small spot and dots amidst extensive faculae. But the magnetic elements began to be disturbed during this second rotation of the spot group on February 16-17.—*A. L. Cortie.*²²

Mr. C. S. Ling, of the United States Weather Bureau aerological station at Drexel, Nebr., observed an aurora from 1:55 to 2:22 a. m. February 17, and Mr. W. A. Bentley, of Jericho, Vt., an aurora on February 19-20.

By the middle of April the rotation of the sun brought the disturbed surface again into a position to affect the earth.

* * * On the 16th of April a medium-sized spot became central. It was probably one of the six spots of the before-mentioned group. It was followed by a small spot some 200,000 miles after and also central about two days later. It was possibly another remnant of the old

²⁰ Science, May 14, 1920, pp. 485-486.

²¹ See *Popular Astronomy*, May, 1920, plates 13-15. *L'Astronomie*, April, 1920, plate 2, contains three pairs of photographs of the aurora of Oct. 4, 1919.

²² Nature (London), April 1, 1920, p. 137.

group, but too small to be of any consequence. It had disappeared by the 19th. * * * on the morning of the 17th telegraph operators noticed a disturbance.—E. D. Roe, jr.²³

Mr. Owen Bryant reports that the "aurora was bothering the wires again on the morning of April 20 [at Calgary]," but the weather did not permit him to observe any display. Auroras were reported as seen in New England on the nights of April 14, 16, 17, 18, 19, and at Jericho, Vt., only, April 20-22. The aurora of the 16th was also seen at Ottawa, Canada, that of the 17th at Plainfield, N. J., and that of the 19th extensively throughout New England, and, possibly, through a rift in the clouds at Washington, D. C.

On the following presentation, a faint aurora was observed at Washington, D. C., on the night of May 9, and another by Mr. W. A. Bentley at Jericho, Vt., and by Prof. G. R. Wieland at New Haven, Conn., on the night of May 15-16. Other auroras have not been reported, and from the waning character of the displays at successive rotations of the sun it appears that the unusual solar activity has ceased.

We shall be fortunate if we ever see the equal of this marvelous aurora. Such are rare indeed anywhere in middle latitudes. (See Table 1.) Four potential auroras

TABLE 1.—A list of the principal auroras from 1914 to 1920, inclusive.¹

Year.	Greatest.	Great.	Unusually brilliant.
1914....	None.....	None.....	None.
1915....	June 16-17.....	None.....	{Oct. 6-7 (Iceland). Nov. 14-15 (Iceland).}
1916....	Aug. 26-27.....	None.....	None.
1917....	{Aug. 9-10. Dec. 16-18.	{Jan. 4. May 15-17.
1918....	Mar. 7-8.....	Aug. 15-16.....	{Feb. 27-28. May 2.
1919....	Aug. 11-12.....	Oct. 1-3.....	
1920....	March 22-23.....	

¹ Many of these displays are described in the MONTHLY WEATHER REVIEW for the years indicated.

may pass unnoticed in the daytime, in the latter half of night, or behind the clouds, for each one that a person can see on a clear evening. We can count only five such great world-wide auroras during the past five years embracing this unusual sunspot maximum. Our turn is not likely to come again for 20 years.

NOTE ON THE HEIGHT AND LOCATION OF THE AURORA SPOTS AND BELT OF MARCH 24, 1920.

By CHARLES F. BROOKS and C. LeROY MEISINGER.

[Weather Bureau, Washington, D. C., May 10, 1920.]

In comparing the notes of various observers of the aurora of the night of March 24-25, it appears that some of the spots and patches observed in various places were identical, but that they appeared in various parts of the sky to the various observers. This makes it easily possible to calculate the altitude of the aurora and determine its location. For example, a certain spot was simultaneously seen from South Hadley, Mass., Concord, Mass., Rochester, N. Y., and Washington, D. C. Prof. Anne S. Young at South Hadley saw it in the southwest at an altitude of about 15°, Mr. Milroy N. Stewart at Rochester saw it in the southeast at about the same elevation, and at Washington it was observed in the northeast-by-north at an elevation of 35° to 40°. While Mr. Fred A. Tower at Concord certainly saw the same spot, the reported elevation seems to have been estimated

somewhat too large, it being reported as 40°. These lines meet in an area over southeastern Pennsylvania and central New Jersey, and trigonometrical calculation shows that its height was about 140 kilometers (87 miles).

Again, the May, 1920, issue of *Popular Astronomy*, pages 307-312, gives some interesting photographs and reports. One of these photographs, taken about midnight, March 24, in Brooklyn, N. Y., shows an auroral spot in the southeast together with several star trails, among which the most conspicuous were those of Mars and Spica. This spot was observed in Washington, between east by south and east-southeast within a few degrees of the horizon. Measuring on the photograph made at Brooklyn it is possible to determine with fair accuracy the angular altitude of the auroral spot at that place, and its center is found to be about 13°. If lines are drawn toward the southeast from Brooklyn and toward a point between east-by-south and east-southeast from Washington, it is found that they intersect in the ocean about 320 km. from Brooklyn and 470 km. from Washington. Using the Brooklyn elevation, we find the altitude of the spot to be about 120 kilometers (73 miles).

Another case, taken in part from the reports in *Popular Astronomy*, is that of an observer in Ann Arbor, Mich., reporting a bright patch in the south about 20° above the horizon at 11 p. m. 90th meridian time. From Washington, this spot appeared in the west-by-north about 7° above the horizon. Calculation shows it to have been about 330 km. south of Ann Arbor, and 610 km. west-by-north of Washington at a height of about 130 kilometers (81 miles).

All these values being in very good agreement, it is reasonable to assume that the display was taking place at that general elevation; or, to take the mean of the three calculations, 130 kilometers (81 miles). Making this assumption as to the altitude, it is possible to locate other spots which were observed from Washington. Such a one was seen in the northwest to northwest-by-west or west-northwest at about 9:45 p. m., appearing as lenticular in form with its lower edge at an elevation of 18° and its upper at 23°. Assuming this to have been actually a flat base and its elevation 81 miles, we find that the more distant edge must have been 400 km. from Washington and its nearer edge about 300 km. This would place it over east central Ohio and western Pennsylvania. Mr. H. D. Pallister, writing from eastern Kentucky, says:

"I also saw the aurora on March 24 about 9:30 p. m. (C. S. T.?) at Wolfpit, Pike County, Ky., and watched it for over one-half hour. As seen here it consisted of undulating flashes of white light radiating from a general northerly direction. The flashes would occur at intervals growing brighter and then die out for a time."

The two spots over eastern and western Pennsylvania early in the evening, grew into a belt stretching from a few hundred miles out to sea, across northern Virginia to southwestern Ohio. Although the belt seemed to move slowly, it was traveling southward at about 60 miles an hour.

THE PHYSICS OF THE AURORA.¹

By W. J. HUMPHREYS.

[Abstract.]

We are fortunate in having collected in one book practically all that is known concerning the aurora:

²³ Science, May 14, 1920, p. 436.

¹ Presented before American Meteorological Society, Washington, D. C., April 22, 1920.